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LOCAL AND PARENTERAL PENICILLIN THERAPY IN THE TREATMENT OF RECENT WAR WOUNDS.¹

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TREATMENT of the wounds of World War II has passed through three clearly defined phases, the evolution of surgery keeping step with changes in the tactical situation of the army.

Firstly, the closed plaster method was employed. This was a continuation of pre-war practice and was suitable for the difficult conditions of retreat and heavy casualties of the early part of the war. Next, when lines of communication, although still long and difficult, became more stabilized, an attempt was made to close wounds by secondary suture and skin grafting as soon as the surface was covered by healthy granulations. Finally, we have once more reached the phase of the two-stage operation by which an attempt is made to close all wounds within a week of wounding. This last method, however, is possible on a large scale only when conditions approach the ideal—the army is advancing, lines of communication are secure and easy, the advanced surgeons are suitably placed, the base hospitals are well forward and ample medical supplies are available. Such conditions were attained in the recent campaigns in North Africa, Italy and western Europe.

The first concerted effort to reintroduce the two-stage operation was made in the Tunisian campaign, with encouraging results. In May, 1943, Professor Florey and his associates carried out the first field experiments, using penicillin on battle casualties in North Africa. I was privileged to see this early work and the new possibilities opened up were obvious (Florey,⁽²⁾ 1944; Jeffrey,⁽³⁾ 1944).

Limited quantities of penicillin which became available early in 1944 were reserved, apart from calcium-penicillin powder, for open fractures of the femur and for special cases. Only a small amount was available to general surgeons for purposes of trial. By August, 1944, however, more abundant supplies from the United States of America came to hand, just in time for the Gothic Line battles (September to November, 1944) and at last a full-scale test was possible. About 25% of the casualties from these battles passed through the forward general hospital to which I was attached as surgical specialist, and this paper deals with the treatment of certain groups of these patients.

The casualties all occurred within the comparatively short period of three months, during which conditions of terrain, weather, forward surgeons, lines

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of communication and surgical technique at the base remained the same. The great majority of the patients described were dealt with by me or under my supervision, and the techniques outlined were standardized as far as possible.

Partly to conserve the stock of penicillin, which was not yet in unlimited supply, but chiefly from a conviction that the method was surgically sound, the wounds were treated for the most part by local therapy alone or local combined with a short course of parenteral therapy. This emphasis on local therapy will be referred to in detail later. Further experience will undoubtedly produce modifications in technique, as the "trial and error" phase of penicillin therapy has by no means yet ended.

The purpose of this paper is to set down and discuss the results of a personal experience in the treatment of recent war wounds by the use of penicillin therapy. The cases will be dealt with under the following headings:

1. The two-stage operation applied to (a) soft tissue wounds treated (i) by delayed primary suture, (ii) by secondary suture; (b) open fractures.
2. Gas gangrene.
3. Secondary hæmorrhage and infected arterial hæmatomata.

THE TWO-STAGE OPERATION OF WOUND CLOSURE.

Early closure of war wounds by delayed primary suture and sometimes by primary suture was practised towards the end of the 1914-1918 war in selected cases.

In this war the method was again tried in the early stages, but owing to the difficult conditions prevailing—armies in retreat, inadequate medical supplies, long and difficult lines of communication—the practice was soon condemned. Many bitter lessons had to be learned by each succeeding group of surgeons until it became established beyond dispute that the primary suture of war injuries was surgically indefensible except for head, face and abdominal wounds.

If it was practicable to hold patients at the forward operating centre, primary suture might be feasible in some cases, in the light of recent experience with penicillin. Such patients would require careful supervision and it is doubtful whether much would be gained by the practice, as the few days' interval between the operations in the two-stage procedure allows the success or failure of the primary operation to become apparent.

It was therefore impossible to modify greatly the closed plaster method with or without late secondary suture and skin grafting until conditions of warfare again became favourable in the Italian campaign. By this time forward surgeons had learned the best methods for dealing with wounds, evacuation of casualties was relatively safe and rapid, and penicillin was available in quantity as the bacteriostatic of choice.

To Brigadier Harold Edwards, consulting surgeon, Continental Military Forces, much of the credit must be given for the large-scale reintroduction of the two-stage method. Under his guidance surgeons were encouraged to become "suture-minded" and to attempt to close as many wounds as possible. The result was that the problem of chronic wound sepsis in this theatre became qualitative instead of quantitative (Edwards,¹ 1945).

The successful treatment of a casualty is the end result of a series of events which begins on the battlefield and ends at the convalescent depot or evacuation hospital.

The object of the two-stage method is to close all wounds as soon as it is safe. For this purpose the procedures employed are delayed primary suture, partial suture with skin grafting, and secondary suture.

The best covering for a wound is normal skin with subcutaneous fat. In default of this a skin graft is a second-rate alternative. Thus every effort was made to suture wounds completely even with some degree of tension. When skin loss was excessive one was forced to suture partially and to skin-graft or to skin-graft alone.

The necessity for early provision of a covering of skin for damaged tissue needs little emphasis. Such a surgical principle is now firmly established. Only after epithelialization is complete do the formation of scar tissue and the fight against infection come to an end. Early wound closure thus results in alleviation of pain, limitation of scarring and deformity, avoidance of chronic sepsis and conservation of manpower, considerations which are of the utmost importance both in peace and war. In the past the great difficulty has been the control of infection, but results will show that penicillin has largely solved this problem.

The successful closure of a war wound depends upon many factors, the most important of which are: (i) an early efficient primary operation at a forward operating centre; (ii) the local introduction of a bacteriostatic into the wound; (iii) satisfactory immobilization of the part and non-interference with the dressings during the journey to the base hospital; and (iv) closure of the wound within seven days at a base hospital, where the patient must be held at least until the sutures are removed.

The principles governing the primary surgery of war wounds are now well established ("Forward Surgery in Modern War"⁽¹⁾ and "Field Surgical Pocket Book"⁽²⁾). The routine followed in this theatre has been succinctly described in a recent article (Stammers,⁽³⁾ 1945).

The high velocity missiles of modern warfare produce such extensive tissue destruction that it is almost impossible to determine accurately the limits of excision necessary. Pathogenic organisms are almost certainly introduced into every wound with indriven air, metallic foreign bodies, pieces of clothing, dirt *et cetera*. The purpose of surgery is to remove as far as possible all damaged and contaminated tissues and accessible foreign bodies and to decompress the wound by fascial incisions so that any remaining organisms may be left to the unimpeded action of the natural defences of the body. The process is assisted by the local introduction of a bacteriostatic. Suture is proscribed.

Where the bacteria are few and the remaining damaged tissues small in amount, the defences of the body will soon turn out the invaders unless they are hindered by tension. In a sutured wound the hyperæmia which should give protection is limited by the unyielding surroundings and finally replaced by ischæmia, and the outpouring of defensive fluids is brought to a standstill when the interstices of the wound are filled; the bacteria, on the other hand, find in the trapped discharges an ideal pabulum and in the anoxic tissues an easy prey. (Ogilvie,⁽⁴⁾ 1945.)

With the wound excised and laid widely open without tension the limb is immobilized and the patient evacuated to the base.

If, by careful early surgery, wounds could be rendered sterile with certainty, the success of delayed suture would not be in doubt. But potential infection remains, as, except in the superficial gutter type wound, it is quite impossible to sterilize the injured area by surgical toilet. It is in the control of this potential infection that the bacteriostatals have proved so valuable.

A controlled series of 1,000 wounds from the Gothic Line battles was studied in detail by Number 1 Penicillin Control Team. The cases in the series reported here are included in their figures. For the purposes of the investigation of the value of chemotherapy in the early treatment of wounds it was arranged with the forward surgeons that patients would be treated alternately with sulphonamide powder and with calcium penicillin-sulphathiazole powder, and that in a certain number of cases no bacteriostatic at

all would be used. Results are summarized briefly as follows. "Infected" means that pyogenic cocci were grown from a clinically clean wound. "Septic" means that pyogenic cocci were grown from a clinically dirty wound.

The organism of initial sepsis was found to be *Staphylococcus pyogenes aureus*. *Streptococcus pyogenes* (hæmolytic streptococcus) was rarely found and never apart from staphylococci.

The incidence of infection before primary operation was 51%.

Among wounds undisturbed during transit and treated by operation alone (no bacteriostatic used), 49% were infected and 23% were septic; of those treated by operation and sulphonamide powder, 43% were infected and 11% septic; of those treated by operation and penicillin-sulphathiazole powder, 25% were infected and 7% septic, when examined at the base hospital. Thus operation alone did not completely remove infection from wounds. Sulphonamide had a bacteriostatic effect, as the sepsis rate was halved. Penicillin-sulphathiazole powder was still more effective. Of 163 wounds dressed during evacuation, 48% were infected with pathogens as against 33% of undisturbed wounds. (Bentley and Scott Thomson,¹¹ 1945.)

The two-stage operation will now be discussed in relation to 509 soft tissue wounds and 184 open fractures. Some of these cases have recently been reported. (Hendry, Gledhill and Price,¹² 1945.)

The following terms require definition: "Delayed primary suture" applies to wounds which are closed within ten days of infliction: the optimum time for suture is five to six days. "Secondary suture" relates to wounds closed after fourteen days, such wounds usually requiring reexcision before suture. "Penicillin powder" means calcium penicillin-sulphathiazole powder, 2,500 units per gramme. "Penicillin tubes" are soft rubber tubes (internal diameter 3.0 to 4.0 millimetres) with three to four lateral openings near one end, which is tied.

Soft Tissue Wounds Treated by Delayed Primary Suture.

The number of soft tissue wounds treated by delayed primary suture was 434. The casualties arrived by air transport or hospital ship on an average five to seven days after being wounded. All had received primary treatment and most had been given varying amounts of sulphonamide by mouth. On arrival the general condition of each patient was assessed, any deficiency in blood volume or hæmoglobin was made good, and after twenty-four hours' rest he was taken to the operating theatre. Here the dressings were removed for the first time with full aseptic ritual, and the wound was inspected with a view to suture.

Wounds fell into three categories: type A, gutter wounds of skin and fat alone or with superficial muscle injury; type B, wounds with penetrating tracks, or through-and-through wounds sometimes associated with a minor incomplete fracture; type C, large lacerated wounds with extensive muscle damage.

Clinical Appearances.

The clinical appearance of the wound was noted and a swab was taken for bacteriological examination, the skin edges being carefully avoided.

Three clinical wound states were noted: (i) "Clean" (324 cases). The edges were free and non-œdematous, the base showed no exudate, and reactive changes were absent. (ii) "Dirty" (99 cases). The surface was covered with exudate, the edges were adherent and beginning to show œdema, and the base had a glazed, greyish appearance. From about 50% of these wounds *Staphylococcus pyogenes aureus* was grown. (iii) "Inflamed" (11 cases). These were the wounds considered unsuitable for suture, as inflammatory

changes were too far advanced. From all *Staphylococcus pyogenes aureus* (++++) and hæmolytic streptococci (+) were grown.

It is important to emphasize the point that the decision to suture a wound was made on the clinical appearances alone. Swabs were taken for bacteriological interest, but a fundamental principle of the second operation is that it must be performed at the first inspection at the base hospital independently of the bacteriological findings. In practice it was soon found that such decisions were completely reliable, as no wound had to be opened up for spreading cellulitis or clostridial infection.

One hundred and ten wounds were "clinically" dirty, showing inflammatory changes of varying degree. In pre-penicillin days all of these would have been rejected for immediate suture, but in only eleven cases was it thought advisable to postpone the operation.

No wound was regarded as too trivial for suture, as the tiny unsutured wound is just as likely to prolong hospitalization as the more extensive one.

Technique of Delayed Primary Suture.

After the bacteriological swab had been taken the wound was covered with a sterile dressing and the surrounding area was widely shaved and washed with soap and water. Towels were placed and the final preparation of the skin was made with saline solution and 1 in 1,000 solution of neutral proflavine in spirit.

Superficial wounds were disturbed as little as possible. Blood clot and tags of devitalized tissue were removed and the edges were gently freed. The whole wound was frosted with penicillin powder and the edges were united by interrupted sutures of silkworm gut or nylon. Sutures were placed about half an inch apart and edge-to-edge apposition was carefully achieved.

In deeper wounds the tract was explored to ensure that the primary operation was adequate. X-ray pictures were always taken in penetrating wounds and accessible foreign bodies were removed. It is advisable to remove foreign bodies of appreciable size, as many cases of clostridial infection or indolent wounds with sinuses are associated with retained metallic foreign bodies and pieces of clothing.

In all type B and C wounds penicillin tubes were used for local instillation of sodium penicillin solution. The tube was passed to the depths of the wound through a separate stab incision about one inch from the suture line. One to four tubes were used, depending upon the site and extent of the wound. Suture was performed as before, with undercutting if necessary to obtain accurate apposition. Vertical mattress sutures were useful. No buried sutures were placed, but, where indicated, dead space was obliterated by deep tension stitches. A certain amount of tension is permissible, but it should not be excessive. Relaxation incisions were used in difficult cases, but extensive flap-swinging procedures were not performed. If closure was not possible, the wound was treated by partial suture followed by Thiersch or patch grafts five to six days later, or by skin grafting alone. Such cases are not included in this series.

The penicillin tube was secured by an encircling suture and led out through the dressings. A sterile swab tied around the doubled end of the tube with coloured tape both sealed the tube and enabled it to be identified easily for ward treatment.

Penicillin Therapy.

The amount of penicillin powder used varied with the extent of the wound and could not be measured accurately. Indeed it is quite likely that equally good results could be obtained in the superficial type of wound, which

usually looks perfectly clean, without any bacteriostatic, as this is frequently washed out by unavoidable oozing from the suture holes.

Instillation Technique: Three cubic centimetres of sodium penicillin solution (500 units per cubic centimetre) were injected twice daily into each tube for five days. A wound thus received 15,000 units per tube. The first injection was made in the theatre at the end of the operation. Prior to each subsequent injection any collection of serum or pus was aspirated. In spite of the careful dressing technique observed (Medical Research Council War Memorandum Number 6⁽¹²⁾), infection with Gram-negative organisms was common. This was not of great consequence in soft tissue wounds of the limbs, but in certain situations, for example in brain wounds, the use of tubes is not without danger. In more recent cases the tubes have been closed at both ends, the aspiration and instillation being carried out by means of a wide-bore needle; but the effect of this modification is not yet apparent.

In a few cases of extensive multiple injuries a short parenteral course of sodium penicillin (200,000 to 300,000 units) was given either alone or combined with local therapy.

After-Treatment.

All wounds, except the most trivial, were suitably splinted and elevated on the patient's return to the ward. No man was allowed out of bed for five days. All patients with severe wounds were kept in bed for at least fourteen days. The dressings were changed on the sixth day, when the tubes were removed. If there are signs of pocketing or excessive tension, the release of a stitch or two at this stage may save the suture. Sutures were all removed on the tenth day. Results were assessed on the fourteenth day.

Assessment of Results.

The patients were divided into three groups according to the bacteriostatic used at the primary operation. All three groups had similar treatment at the second operation, penicillin being used in all cases.

The average time between infliction of the wound and primary operation was seventeen hours, and between infliction of the wound and delayed suture six and a half days. The delay in the initial period was due to the extreme difficulties of weather and terrain encountered by the stretcher bearers. (See Table I.)

TABLE I.
Results of Delayed Primary Suture.

Bacteriostatic at Primary Operation.	Number of Cases.	Cases Rejected.	Grade I Union. (Successes.)	Grade II Union. (Partial Successes.)	Grade III Union. (Failures.)
Penicillin	167	XII	128 (77%)	27 (16%)	12 (7%)
Sulphonamide	197	XII	158 (80%)	21 (11%)	18 (9%)
None	70	11	35 (50%)	15 (21%)	20 (29%) ¹

¹ Included the eleven cases considered unfit for suture.

Three standards of healing were used. Grade I (100% to 90%) comprised those wounds in which healing was complete in fourteen days and those which were dry, with perhaps a small scab covering a stitch hole. Grade II (89% to 50%) comprised wounds which had healed for the most part. There might be a little gaping or superficial discharge, but all healed within a further few days. A few of these required a small skin graft.

Grade III (under 50%) were regarded as failures. Most of them were only relative failures, as, although the wound had broken down in whole or in part, the underlying tissues had always consolidated and the wound was much reduced in size.

Of the 434 wounds, 336 (77%) were completely healed in fourteen days. There is little difference in the groups treated primarily with penicillin or with sulphonamide powder. Out of 167 wounds of the former group 128 (77%) and out of 197 cases of the latter 158 (80%) achieved grade I union. When no bacteriostatic had been used at the primary operation the results were noticeably poorer. Out of 70 wounds 35 (50%) achieved grade I union.

It will be noted that no wound treated primarily with a bacteriostatic was rejected for suture. This means that in a certain number of borderline cases in these groups suture was used. In the "no bacteriostatic" group 11 wounds were rejected as unfit for suture. This controlled series demonstrates the value of local chemotherapy at the primary operation. Quite apart from the figures there was a striking difference in the appearance of the untreated wounds, almost all of which looked dirty.

Two time intervals appear to be important in wound treatment: Interval A, the time in hours between infliction of the wound and the primary operation, and interval B, the time in days between infliction of the wound and the second operation.

In an attempt to assess how these intervals might affect the results of suture, the cases were divided into four groups as follows. Group 1: Interval A is under twelve hours and interval B up to five days. Group 2: Interval A is under twelve hours and interval B is five to ten days or over. Group 3: Interval A is twelve to twenty-four hours or over and interval B is up to five days. Group 4: Interval A is twelve to twenty-four hours or over and interval B is five to ten days or over.

The numbers in these groups are too small to justify the statement of definite conclusions, but the figures (Table II) seem to show (*a*) that, provided wounds are excised within twenty-four hours and sutured within a week, excellent results can be obtained; and (*b*) that the choice of bacteriostatic at the primary operation does not materially affect the result. Without bacteriostatals, however, the results become rapidly worse as the time intervals lengthen.

TABLE II.
Results in Relation to Time of Operations.

Group.	Bacteriostatic at Primary Operation.	Number of Cases.	Number in which Complete Healing Occurred in Fourteen Days.
1	Penicillin	37	32 (87%)
	Sulphonamide	46	39 (85%)
	None	13	9 (69%)
2	Penicillin	38	33 (87%)
	Sulphonamide	33	28 (84%)
	None	21	9 (43%)
3	Penicillin	47	37 (78%)
	Sulphonamide	78	60 (77%)
	None	17	11 (65%)
4	Penicillin	45	36 (80%)
	Sulphonamide	40	31 (80%)
	None	19	6 (30%)

The following brief summaries illustrate the more serious type of case treated:

CASE I.—Private H. received a shell wound of the right buttock on September 10. He was operated on at a forward surgical unit ten hours later. The wound was excised, sulphonamide powder was instilled, a "Vaseline" gauze dressing was applied, and 49,500 units of gas-gangrene antiserum were given. On September 15 he was admitted to a general hospital. On September 16 operation was undertaken. The wound of the upper part of the right buttock was irregular; it measured eight by four inches and the gluteal muscles were grossly lacerated. Incomplete fractures of the ilium and sacrum were present. The wound was mildly infected. The wound was completely sutured and four penicillin tubes were inserted.

During after-treatment 15,000 units of sodium penicillin were given by each tube; 49,500 units of gas-gangrene antiserum were given.

On September 28 the wound was almost completely healed, the suture line being a little moist at the stitch holes. On September 30 the wound was dry and had healed by grade I union. On October 4 the patient was up and was walking with a slight limp. On October 16 he was sent to a convalescent depot with the wound soundly healed.

CASE II.—Fusilier W. received a wound from a high-explosive shell of the left buttock and thigh on September 18. He was operated on at a forward surgical unit twelve hours later. The wound was excised, penicillin powder was inserted and a "Vaseline" gauze dressing was applied; 49,500 units of gas-gangrene antiserum were given. He was admitted to a general hospital on September 22. His general condition was moderately good, his hæmoglobin value was 60%, and two pints of blood were given by transfusion.

On September 23 operation was performed. The wound was very extensive and involved the lower third of the left buttock and almost the whole of the postero-medial aspect of the thigh. Gross laceration of glutei and hamstrings was present. The wound was dirty and there was evidence of incomplete primary excision. Necrotic tissue was excised. The wound was sutured as far as possible with a good deal of tension. Six penicillin tubes were inserted.

During the after-treatment 15,000 units of sodium penicillin per tube were given. On October 2 the sutures were removed. About 50% of success only was achieved, but the wound was clean and greatly reduced in size. The patient's general condition was good. On October 4 daily preparation of the granulating area for skin grafting was undertaken, penicillin powder being used. On October 7 operation was performed, patch split-skin grafts being applied and penicillin powder being used. On October 11 the grafts were successful. On October 20 the whole area was healed, but some skin contracture seemed likely to occur. On October 25 the patient was evacuated "long term", as prolonged rehabilitation would be required.

Failures and their Treatment.

Of the cases in which suture was used, 39 (9.2%) were regarded as failures. The chief causes of failure were: (i) Excessive tension. A certain degree of tension could safely be allowed, but in such areas as the acromion, great trochanter and subcutaneous surface of the tibia tension was frequently followed by failure. (ii) Infection due to improper selection of cases. (iii) Retained foreign bodies. (iv) Presence of sequestra.

The treatment in these cases varied with the extent of the failure. In partial failures the unhealed area was covered later by a Thiersch or patch graft. In other cases complete excision and resuture were performed, as described below. When indicated, foreign bodies and sequestra were removed and suture was again attempted.

Soft Tissue Wounds Treated by Secondary Suture.

Secondary or excision suture was employed for 75 wounds treated fourteen or more days after infliction. By this time the granulation tissue is becoming organized and the healing capacity of the wound is steadily diminishing. Infection and fibrous tissue formation together induce a state of chronicity which must not be allowed to continue.

Technique.

The whole wound, including a margin of skin, was excised down to healthy muscle. The skin edges were carefully approximated as before with as little tension as possible. Wide undercutting was often necessary and occasionally relaxation incisions and local flaps were used. When closure was not practicable partial suture with skin grafting was employed. In this type of case treatment by the instillation method was invariably adopted, two or more tubes per wound being used for five days. The results are set out in Table III.

The results are not so satisfactory as in the primary operations, and this again emphasizes the importance of the early closure of wounds.

TABLE III.
Results of Secondary Suture.

Number of Cases.	Grade I Union. (100%–90%)	Grade II Union. (89%–50%)	Grade III Union. (Under 50%)
75	48 (64%)	17 (23%)	10 (13%)

The Two-Stage Operation Applied to Open Fractures.

Extension of the two-stage procedure to the treatment of open fractures followed naturally when the excellent results of delayed suture of soft tissue wounds became evident. An open fracture was regarded as merely a soft tissue wound complicated by bone damage.

It was decided to treat all battle casualty fractures by a standard method. Patients with fracture of the femur are not included in this series, as they were treated separately by the orthopaedic team, whose results have already been published (McEwan *et alii*,¹¹² 1945).

One hundred and eighty-four patients with fractures were treated from the Gothic Line battles. The cases form a consecutive series. So that the results should give a fair index of what might be expected from penicillin therapy, no selection of cases was made.

To obtain and maintain a high concentration of penicillin at a fracture site would require large doses by the parenteral route. Thus it was believed that local administration was the more logical method.

When a missile passes through soft tissues and fractures a bone, the wound contains blood clot, bone chips, devitalized tissue, foreign bodies and infecting organisms—the so-called “haematoma”. To deal with this thoroughly would necessitate a “wound excision” too radical to be justifiable. It follows that all battle casualty fractures are potentially infected and that, in the early stages, this infection will be limited to the “haematoma”. Scott Thomson has shown that 20% of the strains of *Staphylococcus pyogenes aureus* examined from a series of war wounds in Italy were resistant to the concentration produced by parenteral penicillin therapy (one-tenth of a unit per cubic centimetre), but only half of these grew in 10 units per cubic centimetre and very few in 50 units per cubic centimetre (Bentley and Scott Thomson,¹¹¹ 1945).

Thus the increased concentrations that local therapy provides should be sufficient to deal with many strains which would be resistant to the concentrations produced by parenteral therapy. In this series the instillation method was used in all cases, supplemented by a short parenteral course as a safety measure. A new series, with the local use of penicillin alone, has been commenced.

The introduction of tubes to a fracture site may well be criticized as a potential source of infection, and there is also the risk of sinus formation after their withdrawal; but experience with soft tissue wounds has led us to discount these dangers, and this confidence has been fully justified.

In 102 of the 184 cases the wounds were excised within twelve hours of infliction; all except ten were excised within twenty-four hours. With very few exceptions the primary treatment was efficiently performed, and once more it is emphasized that without early efficient primary excision all other treatment must fail. One cannot expect penicillin to penetrate far into devitalized tissues. All patients received sulphonamide by mouth during transit and most had been given blood and/or plasma transfusions. There was no apparent difference between the wounds treated primarily with penicillin powder and those treated with sulphonamide. As before, all patients were rested for about twenty-four hours after arrival, during which time the loss of blood haemoglobin was made good and an X-ray picture was taken.

On an average the second operation was performed on the sixth day after the infliction of the wound.

Technique of Treatment.

Under "Pentothal" anaesthesia the plaster was cut away and the dressings were removed with forceps. A wound swab was then taken for bacteriological examination and the limb was shaved and prepared as above described.

The wound was now gently explored to determine the extent of the injury and to assess the efficiency of the primary treatment. It was seldom that anything but a minor revision was required. Any easily accessible foreign body was removed, especially if it was near the fracture site. At first, bone chips devoid of periosteum were removed, but subsequent experience seemed to show that they might safely be left, as they frequently behaved as bone grafts and thus encouraged union. The decision to suture was once again made on the clinical appearances alone; bacteriological control is not necessary. Many of the wounds closed were mildly inflamed.

The penicillin tubes were inserted through separate stab incisions about one inch from the wound, and were guided to the fracture site. Two or three tubes were used, depending upon the extent of the damage. Each tube was steadied in position by an encircling suture; this allowed them to be removed easily at the completion of the local treatment.

The technique now varied, depending upon whether or not complete closure was possible. In complete closures the skin edges were freed and carefully approximated by vertical mattress and interrupted sutures of silkworm gut or nylon, the sutures being placed one-third to half an inch apart. Much care was taken to secure accurate apposition.

Every effort was made to secure complete closure, and this often meant wide undercutting and led to a fair degree of tension. No buried sutures were used. Tension, provided it is not excessive, is permissible when there is a good muscular layer between the skin and the bone. This layer is absent, for example, in wounds of the tarsus or of the subcutaneous surface of the tibia. Suture here produces "tentage" and failure will inevitably result.

Complete closure was not always practicable for other reasons; in some cases skin loss was too extensive, in others there was evidence of established infection. In many such cases the wounds were partially sutured. An attempt was made to reduce the wound area to a minimum and to carry out a skin graft or complete suture later. In a few cases of extreme skin loss even partial suture was impossible.

The wound was dressed with dry gauze, the fracture was reduced if necessary, and a closed padded plaster of Paris cast was applied, through which the tubes were brought out. The first injection of sodium penicillin solution was made in the theatre and the tubes were sealed as before.

After-Treatment.

Sodium penicillin solution (3.0 cubic centimetres of a solution containing 500 Oxford units per cubic centimetre) was injected into each tube twice daily for five days (15,000 units per tube). The tubes were aspirated before each injection, as above described. On the sixth day the tubes were eased out of the plaster and the opening in the plaster was covered by a dressing.

Each patient also received 300,000 units of sodium penicillin by intramuscular injection (20,000 units every three hours). This course commenced on the day of operation or before if there was any delay in beginning treatment owing to pressure of work.

Check X-ray pictures were taken and on the fourteenth day the wounds were reexamined in the theatre and the sutures were removed. The position of the fragments was now adjusted if necessary.

When only partial suture had been carried out it was sometimes possible now to complete the closure either by suture or skin graft. A fresh padded plaster cast was then applied. No further inspection of the wound took place until the sixth week. At this time the final assessment was made, as disposal had then to be decided; the hospital was on the line of evacuation and patients could not be kept indefinitely.

Assessment of Results.

Cases were classified into three groups: (i) those in which complete healing occurred; (ii) those in which the fracture was sealed off and a granulating wound was present; (iii) those in which the fracture was still open, either widely or by a small sinus (Table IV).

TABLE IV.
Summary of Results (at Sixth Week).

Method of Treatment.	Number of Cases.	Closed Fractures.		Open Fractures.	
		Skin Healed.	Granulating Wound.	Small Sinus.	Widely Open.
Complete suture	114	93	5	13	3
Partial suture	52	17	15	15	5
Suture impossible	18	Nil	2	3	13
Total	184	110	22	31	2

Of the 184 fractures treated, 132 (72%) were closed by the sixth week. Of these, 110 (60%) were completely closed with sound skin healing; the remaining 22 had healthy granulating wounds. In 52 cases (28%) there was still an open fracture. These last-mentioned figures require explanation, as the term "open fracture" is apt to imply widely open. In 31 of these cases the wound had closed down to a small sinus, and in the majority healing could be expected to occur in a few weeks. In 16 of the cases suture was out of the question owing to excessive skin loss or severe infection.

Table V sets out the results of complete suture as they apply to individual bones.

Of the 114 cases of fracture in which complete suture was performed, 98 (86%) were closed fractures in six weeks. Failures occurred particularly when the bones were inadequately covered by soft tissues, as, for example, in tarsal and tibial fractures.

TABLE V.
Results of Complete Suture (at Sixth Week).

Bone Involved	Number of Cases.	Closed Fractures.		Open Fractures.	
		Skin Healed.	Granulating Wound.	Small Sinus.	Widely Open.
Humerus	30	34	—	4	1
Tibia and fibula	26	16	3	5	2
Fibula	6	6	—	—	—
Radius and ulna	24	23	1	—	—
Scapula	7	5	—	—	—
Tarsals and metatarsals	10	7	1	—	—
Patella	1	1	—	—	—
Clavicle	1	1	—	—	—
Total	114	93	5	13	3

The following cases are examples of complete suture.

Private C., on September 1, received a wound from a high-explosive shell which resulted in an open fracture of the middle of the shaft of the left humerus. Operation was performed at a forward surgical unit twelve hours later. The wound was excised and the foreign body was removed. Penicillin powder was instilled and a dressing of "Vaseline" gauze applied. A thoraco-brachial plaster cast was used.

On September 4 the patient was admitted to a general hospital. Twenty grammes of sulphonamide were given by mouth *en route*. The patient's general condition was good. On September 5 operation was performed. The wounds were four and a half inches long on the anterior and posterior aspects of the middle third of the arm. Gross comminution of the middle of the shaft of the humerus was present, with extensive muscle damage. The wound was clinically clean. (No culture could be grown.) Both wounds were completely sutured, one penicillin tube being inserted into each. A padded brachial spica was applied.

During after-treatment 15,000 units of sodium penicillin were instilled into each tube and 300,000 units were given parenterally. The post-operative course was uneventful. On September 20 the anterior wound had healed. The posterior wound was gaping slightly with a small sinus to the fracture site and a little purulent discharge. From this no culture could be grown. On October 26 both wounds were firmly healed, the fracture was firmly united, and the patient was sent to a convalescent depot.

Lance-Corporal R., on September 2, was wounded by a machine-gun bullet in the right elbow. Ulnar nerve palsy was present. Operation was performed at a casualty clearing station twelve hours later. The wound was excised, penicillin powder was instilled, a "Vaseline" gauze dressing was applied, and the limb was put in plaster of Paris. On September 5 the patient was admitted to a general hospital. His general condition was good. X-ray examination revealed a shattered elbow joint with comminution of the olecranon.

On September 6 operation was performed. There was an irregular wound, six inches by three inches, on the medial aspect of the elbow. The joint was widely open. The ulnar nerve was destroyed for one and a half inches of its length. The olecranon process was excised. The wound was sutured. Two penicillin tubes were inserted and a padded plaster of Paris splint was applied. No culture could be grown from the wound.

During after-treatment 15,000 units of sodium penicillin were instilled into each tube and 300,000 units were given parenterally. On September 20 the wound was almost completely healed. A small sinus into the joint was present, with some serous discharge. A culture of coliform organisms was obtained. A padded plaster splint

was applied. On September 26 the plaster was removed. The sinus was found to be closed and the wound almost healed. Active exercises were ordered. On September 30 the wound was soundly healed. On October 11 the range of movement was from 90° flexion to 130° extension. A nerve-muscle chart confirmed the ulnar lesion. The patient was evacuated to the United Kingdom.

Gunner D., on September 18, received a shell wound from a mortar in the right shoulder. A comminuted fracture of the scapula extending into the shoulder joint was present. Operation was performed at a forward surgical unit eighteen hours after infliction of the wound. The wound was excised, penicillin powder was instilled and a "Vaseline" gauze dressing was used; 33,000 units of gas-gangrene antiserum were given. A thoraco-brachial plaster spica was applied. On September 21 the patient was admitted to a general hospital, 15 grammes of sulphonamide being given by mouth *en route*. His general condition was fair. His hæmoglobin value was 70%. A transfusion of two pints of blood was given. On September 22 operation was performed. There were four extensive wounds, each three inches by four inches long, over the scapular and deltoid regions. Gross laceration of muscles was present. The wounds were clinically clean, though a culture of *Staphylococcus albus* and coliform organisms was grown. Complete suture was performed, penicillin powder and three penicillin tubes being inserted. A padded thoraco-brachial plaster spica was applied.

During after-treatment 15,000 units of sodium penicillin were given by each tube and 300,000 units were given parenterally. The post-operative course was uneventful, and on October 10 all wounds had healed, except for a small sinus to the scapula. On October 20 all wounds had soundly healed. Almost full shoulder movements were present. The patient was sent to a convalescent depot.

Table VI sets out the results of partial suture. It shows that even if complete suture is not possible, partial closure should be attempted. In two out of three cases closure was effected within six weeks and once again failure occurred mainly when there was inadequate soft tissue covering for the bone. It will be seen that about half the wounds with tibial fractures were unsuitable for complete closure. This is to be expected when the well known difficulties of closing soft tissue wounds of the skin are recalled. In spite of this, the results show that partial suture should be attempted as long as tentage is avoided. One amputation was necessary in this group for secondary hæmorrhage with clostridial infection.

TABLE VI.
Results of Partial Suture (at Sixth Week).

Bone Involved.	Number of Cases.	Closed Fractures.		Open Fractures.	
		Skin Healed.	Granulating Wound.	Small Sinus.	Widely Open.
Humerus	5	3	1	1	—
Tibia and fibula	20	5	6	6	3 ¹
Fibula	4	1	3	—	—
Radius and ulna	13	5	5	3	—
Tarsals and metatarsals	9	3	—	4	2
Scapula	1	—	—	1	—
Total	52	17	15	15	5

¹ One amputation for secondary hæmorrhage and gas gangrene.

The following are examples of cases in which partial suture was employed.

Private B. was wounded by a mine on September 1. He had a fracture of the right radius and ulna which extended into the elbow joint, and also multiple flesh wounds. He was operated on at a forward surgical unit eighteen hours later. Many wounds were excised; penicillin powder was instilled and a "Vaseline" dressing was used; a plaster of Paris splint was applied.

The patient was admitted to a general hospital on September 5. His general condition was fair. His hæmoglobin value was 65% and he was given a transfusion

of two pints of blood. X-ray examination revealed a fractured elbow joint and comminuted fractures of the upper third of the radius and ulna.

On September 6 operation was performed. Separate through-and-through wounds of the elbow joint and upper third of the forearm were present. Fractures were present as stated. Clinically the wounds were mildly infected. No culture could be grown. Three wounds were sutured. The wound over the olecranon process was left open. Two penicillin tubes were inserted and a padded plaster splint was applied. In the right thigh and leg there were nine soft tissue wounds. Only three of these were suitable for suture. Three penicillin tubes were inserted. In the left thigh there was a large soft tissue wound which was sutured, one penicillin tube being inserted. In the right shoulder there were four soft tissue wounds which were sutured, penicillin powder being instilled.

During the after-treatment 15,000 units of sodium penicillin were given by each tube and 300,000 units were given parenterally. On September 21 all sutured wounds were healed. Thiersch grafts were applied to the right leg. The elbow joint was closing by granulation. A padded plaster of Paris splint was applied to the arm. On October 1 the elbow was almost healed. The fractures were closed. The grafts were successful. Active exercises were ordered. On October 20 all wounds were healed. Elbow movement was obtained through a range of 90°. The patient was evacuated for prolonged rehabilitation.

Private G. was wounded on September 5 by a high-explosive shell, sustaining a comminuted fracture of the right ulna, and median and ulnar nerve palsies. He was operated on at a forward surgical unit eighteen hours later. The wounds were excised, sulphonamide powder being instilled and a "Vaseline" gauze dressing used; a plaster of Paris splint was applied.

On September 12 the patient was admitted to a general hospital. His condition was good. On September 13 operation was performed. A wound, eight by four inches, was present on the volar aspect of the forearm with gross laceration of the flexor muscles. The median and ulnar nerves were exposed over a wide area. The wound was clinically infected. A culture of coliform organisms and diphtheroids was obtained. Partial suture was performed; three penicillin tubes were inserted and a padded plaster cast was applied.

During after-treatment 15,000 units of sodium penicillin were given by each tube and 300,000 units were given parenterally. On September 28 the sutured portion of the wound was completely healed, leaving a granulating area, two inches by one inch, with a small sinus to the bone. Penicillin powder was instilled and the plaster cast was reapplied. On October 26 the wound was completely healed. Firm union was present. The patient was evacuated to a peripheral nerve centre.

Cases Unsuitable for Suture.—There were 18 cases in which the wounds were unsuited for suture. These comprised four with clostridial myositis and 14 with gross tissue loss and established sepsis. In all these cases the routine treatment was used. At the sixth week all except two were open fractures, but in three cases the wounds had closed by the eighth week after skin grafting.

In dealing with a consecutive series of cases it was inevitable that a number of wounds would be so severe that the limb was endangered. Four major amputations were performed, either because the limb was useless or because continuation of severe infection threatened the patient's life. There were no deaths in the whole series.

Formation of Callus.—In a busy general hospital abroad it is not possible to retain all patients with compound fractures until firm union is established. Conclusions are, therefore, incomplete, and based mainly on findings with respect to certain bones.

Table VII sets out the disposal of the patients with various fractures at the sixth week, with the extent of union then present. Estimates were made from clinical and radiological findings.

It will be seen that of all the patients with fractures which were either partially or completely closed, one-third were discharged to a convalescent depot by the sixth week; good callus was present in 114 cases (69%).

Results were best in the case of the humerus. Thirty-nine out of 44 patients were discharged with the bone firmly united. Of these, 19 went to

TABLE VII.
Disposal of Complete and Partial Sutures at Sixth Week.

Bone Involved.	Number of Patients.	To Convalescent Depot with Firm Union.	Evacuated "Long Term" or Remaining.	
			Good Callus.	Poor Callus.
Humerus	44	19	20	5 ¹
Tibia and fibula	46	3	23	20
Fibula	19	5	5	—
Radius and ulna	37	17	5	15 ²
Scapula	8	6	—	—
Tarsals and metatarsals	19	5	—	12 ³
Patella	1	1	—	—
Clavicle	1	1	—	—
Total	166	57	57	52

¹ Two with marked bone loss.

² Nine with marked bone loss.

³ Five with bone loss.

the convalescent depot and 20 were evacuated to the United Kingdom for nerve palsies or associated injuries.

It appears, therefore, that, except when there was much bone loss, union was as rapid as if the wounds had been closed and accidental injuries.

Bacteriology.—Unsuccessful attempts were made to grow cultures in 41% of cases. In 40% *Bacterium coli*, *Pseudomonas pyocyanea* or diphtheroids were grown. *Staphylococcus pyogenes aureus* was cultured in 6% and clostridia in 12%. This is a lower incidence of staphylococci than occurs in soft tissue wounds, and this may be due to more careful application of bacteriostatics by the forward surgeons in fracture cases.

From the majority of the wounds which were open at the first plaster change Gram-negative organisms were grown. Penicillin seems to favour such growth, but there was no evidence that the presence of these organisms delayed healing, and no persistent bone infection could be ascribed to such a cause. The cases with established clostridial infection are discussed in the next section.

Failures and their Treatment.—Without selection of cases it was inevitable that a certain number of failures would result. These occurred especially, as stated, in tibial and tarsal fractures, for the reasons given.

In the treatment of these cases the closed plaster method was temporarily abandoned and a policy of repeated dressings substituted. For this purpose the limb was suitably supported either in Thomas, Braun or plaster gutter splints.

Some of these fractures were severe and were characterized by considerable bone loss, and the wisdom of attempting to save doubtfully useful limbs might well be questioned. Nevertheless, it was decided, in most cases, to make further attempts to heal the wound, so that eventually the patient could at least make trial of the limb. Such a policy is justifiable, provided the patient's life is not endangered and there is a fair prospect of a useful limb in a reasonable time.

Various treatments were tried, but greatest success was obtained by alternating penicillin therapy with the use of neutral proflavine either in 1 in 1,000 aqueous solution or as an emulsion, along the lines suggested by Poate⁽¹⁶⁾⁽¹⁷⁾ (1944). Removal of foreign bodies and sequestra was required in many cases.

The role of penicillin in chronic bone infection is by no means yet established. In the resistant cases the doses now used are probably far too small. Stronger solutions for local use (1,000 to 2,000 units per cubic centimetre) and more prolonged parenteral courses are indicated.

Work is proceeding on the production of an acridine derivative compatible and synergic with penicillin (Poate, 1945) and, if it is successful, the problem of chronic bone sepsis will be appreciably nearer to solution.

The following are examples of failure in the treatment of fractures.

Sergeant B. was wounded by a piece of high-explosive shell on September 30; he had a comminuted fracture of the left tibia and a lacerated wound of the right leg. He was operated on at a forward surgical unit three hours later. The wound was excised, penicillin powder was instilled, a "Vaseline" gauze dressing was used and a "Tobruk plaster" applied.

On October 7 he was admitted to a general hospital. His general condition was fair. His hæmoglobin value was 70%, and two pints of blood were given by transfusion. X-ray examination revealed a comminuted fracture of the tibia at the junction of the upper and middle thirds, with a considerable amount of bone loss. The fibula was intact. The position was satisfactory.

Operation was performed on October 8. In the left leg there were through-and-through wounds with extensive skin loss over the fracture site. Gross comminution was present. The wounds were badly infected. Two tubes were inserted and a padded plaster cast was applied. Minor revision showed that the wound was unsuitable for suture. (A culture of *Staphylococcus aureus* (++) and coliform organisms was obtained.) In the right leg there was a mildly infected superficial wound. Penicillin powder was applied and the wound was sutured.

During after-treatment 17,500 units of sodium penicillin were given by each tube; 300,000 units were given parenterally, and 49,500 units of gas-gangrene antiserum were given.

On October 27 the plaster cast was removed. The fracture was widely open, with a large area of bare bone. Pus was present. Proflavine emulsion was applied. The limb was supported on a Braun splint.

At this time an opinion was given that amputation might have to be considered soon, as it was doubtful whether it was justifiable to attempt to save the limb owing to bone loss and severe sepsis. A culture of aerobic coliform organisms and of anaerobic clostridia was obtained.

On October 30 the hæmoglobin value was 70%. A transfusion of two pints of blood was given. The patient's general condition was satisfactory. Daily dressings with proflavine emulsion were ordered.

On November 10 the operation of sequestrectomy was performed. One large loose bone fragment was removed. Proflavine emulsion was used and a padded plaster cast was applied. A window was to be cut in the plaster in three days. A culture of aerobic coliform organisms and diphtheroids and of anaerobic streptococci was obtained. On November 14 a window was cut in the plaster cast and the wound was still badly infected. Repeated dressings with proflavine emulsion were ordered. On November 24 much improvement was noted; the discharge was less.

On December 7 the wound was almost healed. X-ray examination revealed extensive bone loss for two inches anteriorly, but there appeared to be continuity by a thin bar of bone posteriorly. On December 14 a lightly padded plaster cast was applied. The wound was healed. Long-term evacuation was ordered, possibly for bone grafting.

Penicillin did not succeed in this case in controlling the well-established local infection, but it probably was helpful in maintaining the patient's general condition in the early phases. After further surgical intervention the wound responded rapidly to repeated proflavine emulsion dressings and after bone grafting a useful limb should result.

Private S. was wounded on September 2 by a high-explosive shell fragment, sustaining open fractures of the left mid-tarsus. He was operated on at a forward surgical unit seven hours later. The wound was excised. A large metallic foreign body and a piece of shoe leather were removed from the region of the mid-tarsal joint. Penicillin powder was instilled, a "Vaseline" gauze was used, and a plaster cast was applied.

On September 4 he was admitted to a general hospital. His general condition was fair. He complained of a good deal of pain. X-ray examination revealed shattering of the anterior part of the *os calcis*, the cuboid, and the lateral cuneiform bone. On September 5 operation was again performed. A foul-smelling septic wound one and a

half inches long was present on the lateral aspect of the mid-tarsus. Loose bone fragments were removed. One penicillin tube was inserted, a "Vaseline" gauze dressing was used, and a padded long-leg plaster cast was applied. (Aerobic diphtheroids were grown in culture; no anaerobic organisms were recovered.)

During after-treatment 15,000 units of sodium penicillin were applied locally and 300,000 units were given parenterally. On September 18 progress had been uneventful and the patient's general condition was satisfactory. The wound was healing but there was a wide sinus to the mid-tarsus discharging pus. (No organisms were recovered in culture.) A proflavine emulsion dressing was applied.

On October 5 the patient's temperature was 103° F. He was complaining of severe pain in the foot. The plaster cast was cut away. Suppurative arthritis of the tarsus was present. A transfusion of two pints of blood was given. On October 6 an incision was made along the medial side of the tarsus. Numerous small sequestra were removed. Through-and-through drainage was established. Two penicillin tubes were inserted and a padded plaster cast was applied.

During after-treatment 15,000 units of penicillin were given by each tube. On October 12 the plaster was cut away. The wound was still discharging freely. The patient had less pain. His general condition was satisfactory. A proflavine drip (1 in 1,000) was set up. Irrigation three times a day was ordered for five days.

On October 17 improvement was noted. Daily proflavine emulsion dressings were ordered for four days and then every two to three days. On October 25 the wounds were closing rapidly. Healthy granulation tissue was forming. The patient's general condition was excellent. On November 8 the wounds had healed. The patient was evacuated to the United Kingdom.

This case is typical of six others in which similar extensive injuries of the tarsal and metatarsal bones were present. In most of the cases amputation would have been justified, as the ultimate functional result will be poor, but the patients will at least have the opportunity to put the limb to the test. To secure healing the treatment must be carefully supervised, as drainage must be free at all times and frequent sequestrectomies may have to be performed. A great deal of the success was due to the careful dressings which were performed by an enthusiastic nursing staff. The initial dosage of penicillin was far too small. It is in these cases that the strength of the penicillin solution and the duration of the instillations might well be increased. Repeated dressings with neutral proflavine, either in solution or emulsion, undoubtedly contributed to the final result.

PENICILLIN IN GAS GANGRENE.

Clostridial infection of war wounds was uncommon during the desert battles. This was not unexpected, as conditions of climate, terrain and the light clothing of the troops were unfavourable for the growth of such organisms. (MacLennan,⁽¹⁾ 1943, MacLennan and McFarlane,⁽²⁾ 1944.) The incidence of the condition appears to have increased, however, during the Sicilian and Italian campaigns, and a series of cases has already been published. (Jeffrey and Scott Thomson,⁽³⁾ 1944.)

The Gothic Line battles were fought in cold, wet weather and further cases were expected. During the period September to November, 1944, 2,951 casualties were admitted to this hospital; of these, 33 developed gas gangrene—an incidence of 11 cases per thousand. Only one patient died. A separate report on these cases has already been published (Gledhill,⁽⁴⁾ 1945).

Until recently, published figures have shown a mortality from gas gangrene ranging from 30% to 60%. Such reports have usually concerned cases occurring at the casualty clearing station level, and these are almost always of the fulminating type. My fifteen months' experience of forward surgery with a field surgical unit in North Africa and Italy confirms this.

Most of the cases discussed here occurred from three to five days after wounds were inflicted, and presumably might be of a lower degree of severity, but at least ten of them were of the fulminating type. Penicillin therapy has been the only significant addition to treatment.

Diagnosis.

It is too late to await a laboratory diagnosis of gas gangrene. In any case, many wounds are contaminated with clostridia without resultant harm. The diagnosis was made on the well-known clinical signs and symptoms. Confirmation was obtained in every case by a wound swab and muscle culture.

Pain in the affected area was the most common symptom. There was usually a pyrexia of low degree (100° to 101° F.), with a rapid, running pulse of 120 to 130 beats per minute. The greyish, anxious facies, with circumoral pallor, and often a slight icteric tinge, together with peculiar mental changes varying from euphoria to delirium, left little doubt that immediate investigation was necessary. In the theatre the characteristic musty, "dried-fish" odour, the sero-sanious discharge, the greyish non-contractile muscle, and sometimes the presence of crepitus, soon confirmed the diagnosis. In the more advanced cases the limb was cold and mottled, with skin blebs filled with brownish fluid, and there were pronounced signs of severe general toxæmia.

To summarize, the most reliable symptoms and signs of clostridial infection were: pain or heaviness in a limb; raised pulse rate with only moderate pyrexia; mental changes; icteric tinge of the facies with circumoral pallor; low blood pressure suggesting a condition of profound shock with insufficient reason; characteristic odour and lifeless appearance of the muscles, which ranged in colour from "brick-red" to "blue-black". Crepitus was not always found. Its presence is not necessary to establish the diagnosis, nor is its extent a reliable guide to the level of infection in subjacent muscles. It is usually found in the subcutaneous tissues, well in advance of the underlying muscle involvement. This is an important point, especially in the difficult case of upper thigh infection, as it may be possible to amputate successfully through the middle or upper parts of the thigh even though the tell-tale brownish, bubbly fluid is present in the skin flaps (Case XVII).

Site.

The site incidence is shown in Table VIII.

TABLE VIII.
Site Incidence.

Site.	Number of Cases.
Thigh	14
Leg and foot	11
Shoulder and arm	4
Buttock	2
Forearm and hand	2
Total	33

Twenty cases were associated with fractures. In four cases a major blood vessel was damaged. Almost all of the patients had primary surgical treatment within twenty-four hours of being wounded. The wounds were usually caused by high-explosive shells, mortar bombs or mines. Only four cases followed wounding by rifle or machine-gun bullets.

Clinical Types.

Three clinical types of the infection were seen.

1. *Gas Abscess* (six cases). This distinct type of clostridial infection was characterized by a swollen, tense, painful limb with localized œdema and

induration. There was almost invariably a metallic foreign body, to which pieces of clothing were attached, situated in a cavity filled with foul-smelling pus and gas. The muscles were not involved beyond the wall of the abscess cavity. Signs of general toxæmia were not severe in this group.

2. *Clostridial Myositis* (17 cases). In this type of case there was always extensive muscle necrosis with swelling and induration, and frequently, but not invariably, crepitation. Isolated muscle groups were sometimes alone involved, but more usually there was widespread infection of all the muscles along the track of the missile. In some cases the muscles were "brick-red" in colour; in others they were greyish-purple and they did not contract on stimulation. This lack of response to stimulation is a fairly reliable guide to the extent of muscle death. However, when less radical excision of muscle was deliberately performed, some recovery seemed to take place in tissue the viability of which had been in doubt. Signs of general toxæmia were well marked in this group.

3. *Fulminating Gas Gangrene* (10 cases). Ten cases were classified as fulminating. All the patients presented the picture of grave toxæmia characteristic of this type of case. The local signs were those of clostridial myositis of severe degree, with the viability of the limb frequently in doubt. The general condition varied from semi-coma to muttering delirium.

TABLE IX.
Clinical Types of Case.

Gas Abscess.	Clostridial Myositis.	Fulminating Toxæmia.
6 cases.	17 cases. (True gas gangrene.)	10 cases. (True gas gangrene.)

Treatment.

Surgery.

The surgical treatment of gas gangrene is based on the fact that at first the clostridial infection is confined to a localized area of devitalized muscle. The general signs and fatal outcome are produced by toxins generated at the site of infection. Organisms are rarely grown in culture from the blood stream. The logical mode of attack, therefore, is to remove this focus of infection by early radical surgery. This has usually meant amputation or extensive muscle excision. This principle of early efficient surgery must still be maintained, but increasing experience with penicillin and the sulphonamide group of drugs leads one to hope that in the future a more conservative approach may be possible in many cases.

In this series, as one's confidence in penicillin grew, it was decided to be less radical in some cases and, as a result, limbs were unquestionably saved (Cases XI, XII, XXV).

When amputation was not imperative the wound was opened up widely and all non-viable tissue was excised, but the anatomical territory supplied by any damaged blood vessel was carefully borne in mind. If a localized muscle group was involved it was excised completely (Cases VII, XI, XXVI). If in doubt about the extent of excision required, one tended to be more conservative than formerly, and to place more reliance on the bacteriostatics.

No hard and fast rules to suit all cases can be laid down. Each case must be carefully assessed in the light of experience and the appropriate

treatment given. The aim must be to control completely the local focus of infection.

Penicillin tubes were now inserted into the depths of the wound, which was left widely open. Two or three tubes were required per case. A few wounds were partially sutured, but this practice is not generally recommended as tension should be avoided until the outcome has been decided. There is always a certain amount of necrotic tissue to separate in these cases, even after a careful wound toilet, and free drainage for this should be allowed.

Post-Operative Procedure.

Blood Transfusion.—Every patient had transfusions of two to four pints of whole blood, the administration commencing as soon as possible after diagnosis and continuing after operation. Repeated transfusions were required in some cases. Fresh blood was used as far as possible. The value of whole blood as an immediate measure to combat shock and toxæmia is well established, and one felt that it was extremely valuable in these cases.

Gas Gangrene Antiserum.—All patients had gas gangrene antiserum after operation. The first dose of 49,500 units [three bottles of polyvalent (Burroughs Wellcome and Company) antiserum, 9,000 *Clostridium welchii*, 4,500 *Clostridium septicum*, 3,000 *Clostridium ordalii* per bottle] was given with the blood. This dose (49,500 units) was repeated daily for three to four days as indicated.

Penicillin.—When penicillin was used locally the usual dosage was a total of 17,500 Oxford units per tube; 2,500 units were instilled into each tube at the end of the operation, and this was followed by 1,500 units twice daily for five days (the strength of the solution was 500 units per cubic centimetre). In a few cases (V, X, XI, XIII, XXV, XXVI) this dosage was increased owing to the extreme severity of the condition.

When penicillin was given parenterally, from 300,000 to 500,000 units were given in each case by three-hourly intramuscular injections of 20,000 units (10,000 units per cubic centimetre). The issue in gas gangrene is usually determined in 24 to 72 hours, so prolonged treatment is not required.

Sulphathiazole.—Most patients were given an oral course of 25 to 30 grammes of sulphathiazole. A few patients had sulphadiazine given intravenously or sulphonamide applied locally.

Bacteriology.

A wound swab and a piece of muscle were taken for cultural examination in each case. Clostridia were grown in all cases, but facilities were not available for the complete identification of the type of organism. Aerobic cultures usually comprised coliform organisms and diphtheroids. Other pyogenic organisms were rarely found.

Clostridia are common contaminants of war wounds, and their presence is not of great significance in the absence of clinical signs of infection. During the period under review clostridia were grown from 132 separate wounds. In some cases clostridia were still grown long after the toxæmia had been brought under control. Whilst in most instances no relapse occurred, in one or two cases local abscesses had to be drained, and in one case the infection flared up and reamputation was required (Case XIV).

Clinical Course.

As a rule, response to the above treatment was rapid and dramatic. Within twenty-four hours the patients felt better and began to eat and sleep

well. This recovery of general well-being, frequently before the fall in temperature, is a regular feature of patients on penicillin therapy.

Patients with gas abscess promptly lost their pain as the local condition subsided. Secondary suture was carried out after eight to ten days, but this should never be considered until the wound is perfectly quiescent. Further penicillin was used locally for all secondary sutures.

Patients with clostridial myositis usually gave little cause for anxiety after the first twenty-four hours, and at the first change of dressing (six to seven days) a dramatic alteration had taken place in the appearance of the wounds. A line of demarcation had now formed between healthy, contractile muscle and sloughing necrotic tissue, showing that the gangrenous process had been arrested. The sloughs were wiped away, a healthy granulating wound being left, which, in a few cases, was sutured at once, but usually was left open for a further few days to be on the safe side. Skin grafting was eventually necessary in some cases.

In the more severe fulminating cases the issue was not decided for forty-eight to seventy-two hours. After this period, however, the same remarkable change in well-being occurred, with loss of pain and recovery of appetite, and progress was thenceforth uneventful.

Illustrative Cases.

The cases are set out briefly in Table X, but the undernoted detailed reports will give a better idea of the type of lesion dealt with.

CASE VI.—Private K. had a shell wound (high explosive) with an open fracture of the humerus and scapula. A gas abscess occurred in the scapular muscles.

He was wounded on September 5 and was operated on at a forward surgical unit twelve hours later. He had severe comminuted fractures of the upper end of the humerus, the spine of the scapula and the acromion process. Excision was performed. No bacteriostatic effect was noted. Gas-gangrene antiserum, 16,500 units, was given.

On September 9 he was admitted to a general hospital. His general condition was fair. He had some pain in the shoulder. His temperature was 100° F. and his pulse rate 110 per minute.

At operation a penetrating wound of the upper part of the arm was found and the shoulder joint was disorganized. A large shell fragment (three inches by one inch) was removed by a counter-incision over the scapula. Several pieces of clothing were removed from the missile track. A foul-smelling purulent discharge came from the wound. The muscles were oedematous and greyish. Some crepitus was present. The anterior wound was partially sutured and one tube was inserted. The posterior wound was left open, one tube being inserted.

During after-treatment one pint of blood was given and 49,500 units of gas gangrene antiserum; 35,000 units of penicillin were inserted locally. A parenteral course of penicillin consisting of 720,000 units was given. On September 10 the patient was better; 49,500 units of gas-gangrene antiserum were given and a culture of clostridia was obtained. On September 25 secondary suture was performed and the fracture was closed. By October 5 both wounds were completely healed. Long-term evacuation was decided on, as shoulder movements were poor and prolonged rehabilitation was required.

This was a borderline case between gas abscess and clostridial myositis. The remarkable change in the appearance of the wounds between the operations had to be seen to be believed. The fracture was closed within twenty days of the wounding. The total therapy given was penicillin, locally 35,000 units and parenterally 720,000 units; 99,000 units of gas-gangrene antiserum were given.

CASE XIV.—Partisan O. suffered from gas-gangrene in an amputation stump below the left knee, a clostridial abscess in both lungs and suppurative arthritis of the left knee joint.

He was wounded on October 18, amputation was performed below the knee and primary suture was carried out at a field unit. On October 20 the sutures were removed at a field surgical unit and 33,000 units of gas-gangrene antiserum were given. On

TABLE X.
Details of Cases.

Case Number.	Lesion.	Fracture.	Major Vessel Damaged.	Muscle Groups Involved.	Type of Disease.	Operation.	Amputation.	Therapeutic Gas (Gangrene, Anti-serum, (Units.))	Therapeutic Penicillin. Local. (Units.)	Parenteral. (Units.)	Sulpha-Drugs. (Grammes.)	Result.
1	G.S.W., ¹ right thigh. (H.E.), ² shoulder.	Great trochanter, scapula.	—	Glutei.	Myositis.	Partial ex-	—	99,000	35,000	300,000	25	Recovery.
2	S.W., (H.E.), ² thigh.	—	—	Subscapularis, supra-infraspinati.	Myositis.	Removal of foreign body by incision.	—	99,000	35,000	300,000	—	Recovery.
3	S.W., (H.E.), ² thigh.	—	—	Hamstrings.	Myositis.	Partial ex-	—	49,500	35,000	300,000	25	Recovery.
4	S.W., (H.E.), ² thigh.	Great trochanter.	—	Quadriceps and adductors.	Abscess.	Removal of foreign body by partial excision.	—	49,500	35,000	480,000	—	Recovery.
5	S.W., (H.E.), ² thigh.	—	—	<i>Vastus lateralis.</i>	Myositis.	Partial excision.	—	400,000	144,000	—	25	Recovery.
6	S.W., (H.E.), ² shoulder.	Humerus and scapula.	—	Infraspinatus.	Abscess.	Incision.	—	99,000	35,000	720,000	25	Recovery.
7	S.W., (H.E.), ² thigh, perforated wound.	Femur and ischium.	—	<i>Vastus lateralis, rectus femoris.</i>	Fulminating.	Excision, later amputation.	Hip joint.	108,000	52,500	1,320,000	30	Died.
8	S.W., (H.E.), ² leg.	Tibia and fibula.	Anterior tibial.	Anterior tibial peronei.	Myositis.	Incision, removal of foreign body.	—	99,000	52,500	500,000	25	Recovery.
9	S.W., (H.E.), ² leg.	Tibia.	Posterior tibial.	Calf.	Myositis.	Incision.	—	99,000	35,000	300,000	25	Recovery.
10	S.W., (H.E.), ² forearm wound.	—	—	Flexors.	Myositis.	Incisions.	—	99,000	35,000	300,000	25	Recovery.
11	Mine wound, hand.	Carpus, metacarpus.	—	Thenar.	Fulminating.	Excision.	—	297,000	150,000	1,000,000	30	Recovery.
12	S.W., (H.E.), ² thigh and leg.	Tibia and fibula.	—	Quadriceps, anterior tibial peronei.	Fulminating.	Incisions for removal of foreign bodies.	—	148,500	230,000	800,000	30	Recovery.
13	G.S.W., right thigh.	—	—	Quadriceps.	Abscess.	Incision.	—	49,500	35,000	300,000	25	Recovery.
14	G.W., (M.G.), ² leg.	Tibia and fibula.	—	Calf.	Fulminating.	Amputation.	Mid-thigh.	100,000	70,000	1,000,000	30	Recovery.
15	S.W., suppurating knee, amputated stump.	Femur.	—	All thigh.	Fulminating.	Drainage.	—	148,500	35,000	500,000	30	Recovery.

¹ G.S.W. = Gun-shot wound.² S.W. (H.E.) = Shell wound (high explosive).³ G.S.W. (M.G.) = Gun-shot wound (machine gun).

TABLE X.—Continued.
Details of Cases.—Continued.

Case Number.	Lesion.	Fracture.	Major Vessel Damaged.	Muscle Groups Involved.	Type of Disease.	Operation.	Amputation.	Therapeutic Gas Gangrene Anti-serum. (Units.)	Therapeutic Penicillin.		Sulphathiazole. (Grammes.)	Result.
									Local. (Units.)	Parenteral. (Units.)		
16	S.W. ¹ (H.E.), leg. thigh.	Tibia and fibula.	—	Calf.	Abscess.	Incision.	—	49,500	15,000	300,000	25	Recovery.
17	S.W. (H.E.), thigh.	—	Femoral.	Thigh and calf.	Fulminating.	Amputation.	Upper thigh.	148,500	30,000	500,000	40	Recovery.
18	S.W. (H.E.), foot.	Metatarsals.	—	Plantar.	Myositis.	Incision.	—	49,500	30,000	300,000	25	Recovery.
19	Miner wound.	Tibia.	—	Anterior tibial and peroneal.	Myositis.	Partial suture.	—	49,500	45,000	300,000	25	Recovery.
20	Miner wound.	Tibia and fibula.	—	Anterior tibial.	Myositis.	Partial excision.	—	99,000	45,000	500,000	25	Recovery.
21	S.W. (H.E.), arm.	Humerus.	—	Biceps and triceps.	Myositis.	Incision.	—	148,500	30,000	300,000	25	Recovery.
22	S.W. (H.E.), thigh.	—	—	Quadriceps.	Myositis.	Incision for removal of foreign bodies.	—	148,500	—	600,000	25	Recovery.
23	G.S.W., ² right	—	—	Calf.	Myositis.	Incision.	—	99,000	30,000	500,000	25	Recovery.
24	S.W. (H.E.), thigh.	—	—	Quadriceps.	Myositis.	Partial suture.	—	99,000	35,000	300,000	25	Recovery.
25	Miner wound.	—	—	Quadriceps.	Fulminating.	Drainage.	—	247,500	290,000	500,000	25	Recovery.
26	S.W. (H.E.), shoulder, perforated chest.	Scapula.	—	Infraclavicular.	Fulminating.	Excision.	—	108,000	45,000	500,000	25	Recovery.
27	S.W. (H.E.), thigh.	—	—	Quadriceps.	Myositis.	Incision for removal of foreign body.	—	148,500	112,500	600,000	25	Recovery.
28	S.W. (H.E.), thigh.	—	—	Quadriceps.	Myositis.	Incision.	—	49,500	—	480,000	25	Recovery.
29	Miner wound.	—	—	Quadriceps.	Fulminating.	Amputation.	Mid-thigh.	148,500	45,000	500,000	25	Recovery.
30	S.W. (H.E.), leg.	Tibia and fibula.	Posterior tibial.	Calf.	Abscess.	Incision.	—	99,000	30,000	500,000	25	Recovery.
31	S.W. (H.E.), foot.	Metatarsals.	—	Plantar.	Myositis.	Amputation.	Below knee.	99,000	30,000	540,000	25	Recovery.
32	S.W. (H.E.), buttocks and thigh.	—	—	Cluted right and left hamstrings.	Fulminating.	Partial excision, cystostomy, cystostomy, partial excision.	—	185,000	—	500,000	25	Recovery.
33	S.W. (H.E.), thigh.	—	—	Quadriceps.	Abscess.	Partial excision.	—	49,500	35,000	300,000	25	Recovery.

¹ S.W. (H.E.)—Shell wound (high explosive).

² G.S.W.—Gun-shot wound.

TABLE XI.
Time Interval and Prophylaxis.

Case Number.	Interval Time between Injury and Primary Operation.	Interval in Days between Injury and Recognition of the Disease.	Prophylactic Gas Gangrene Antiserum. (Units.)	Prophylactic Penicillin.	
				Local. (Units.)	Parenteral. (Units.)
1	15 hours.	3	49,500	—	—
2	18 hours.	5	—	Powder.	—
3	12 hours.	5	33,000	—	—
4	11 hours.	4	—	Powder.	—
5	24 hours.	1	—	—	—
6	12 hours.	4	16,500	—	—
7	11 hours.	2	99,050	—	—
8	24 hours.	4	33,000	—	—
9	? 12 hours.	1	49,500	—	400,000
10	24 hours.	2	—	—	—
11	16 hours.	5	—	Powder.	—
12	18 hours.	5	148,500	—	300,000
13	7 hours.	17	—	—	—
14	12 hours.	5	33,000	—	—
15	?	7	—	35,000	300,000
16	12 hours.	6	—	Powder.	—
17	12 days.	26	49,500	35,000	—
18	12 hours.	8	—	—	—
19	22 hours.	3	—	Powder.	—
20	? 20 hours.	6	148,500	—	150,000
21	4 hours.	4	—	Powder.	—
22	20 hours.	1	—	—	—
23	20 hours.	4	—	—	—
24	10 hours.	4	—	Powder.	—
25	16 hours.	5	16,500	Powder.	100,000
26	4 days.	9	49,500	Powder.	360,000
27	22 hours.	5	33,000	—	285,000
28	18 hours.	10	—	—	—
29	18 hours.	5	99,000	—	360,000
30	20 hours.	4	22,500	Powder.	200,000
31	18 hours.	2	—	Powder.	—
32	20 hours.	5	—	—	1,450,000
33	?	4	—	—	—

the following day he was admitted to a general hospital in fair condition, but complaining of some pain. On October 23 his temperature was 103° F. and his pulse rate 120 per minute. The flaps were opened up and the muscles were found to be necrotic and crepitant as a result of gas gangrene. During after-treatment (a) two pints of blood were given and one pint of plasma, (b) 66,000 units of gas-gangrene antiserum were given, (c) 500,000 units of penicillin were given parenterally, (d) 30 grammes of sulphathiazole were given. An anaerobic culture of clostridia was obtained.

On October 24 the patient complained of pain on the right side of the chest; dullness was present at the base of the right lung and the patient was seen by a medical specialist (Major F. D. Hart). On October 28 the patient's temperature was 102° F. and the wound was cleaner and painless. On November 2 a transfusion of three pints of blood was given; the temperature was 99° F. On November 7 the stump was quiescent; a few loose sloughs were removed and a proflavine emulsion dressing was applied, the flaps being left open. It was thought that the wound would soon be ready for suture. On November 10 the patient had mucopurulent sputum and râles were audible at the base of the right lung.

On November 13 the wound, which was clean, was loosely sutured and two penicillin tubes were inserted. The treatment after this operation included administration of the following: penicillin, locally 17,500 units per tube, and parenterally 300,000 units; gas-gangrene antiserum, 82,500 units; three pints of blood.

On November 15 the patient's temperature was 103° F. Cough was present and the purulent sputum contained blood. The percussion note was impaired at the base of the lung posteriorly, with bronchial breath sounds. A course of sulphapyridine was given.

On November 17 the patient's breath was fetid. Signs suggesting lung abscess, possibly clostridial, were present at the right base and signs at the left base were also noted. On November 18 copious, foul-smelling, blood-stained sputum was present. Cough was easier. The patient had slight but definite clubbing of the fingers. X-ray examination showed a high right cupola of the diaphragm with lack of translucency suggesting fluid overlying pneumonia. A hazy opacity was present at the base of the left lung. The patient's general condition was better. Postural drainage of the right lung produced copious, mucopurulent, blood-stained sputum. The temperature was

99° F. Sputum yielded an aerobic culture of coliform organisms, hæmolytic streptococci and *Staphylococcus albus*; an anaerobic culture of clostridia was grown.

On November 26 X-ray examination showed a fluid level in a lung abscess in the upper part of the lower lobe of the right lung. A resolving small collection of pleural fluid was present.

On December 3 the patient's temperature was raised. The chest condition was improved and sputum was less. The medical specialist did not think that the fever was due to the patient's chest. On December 5 the temperature was 104° F. and the pulse rate 120. Severe pain in the left knee joint was present. Examination revealed an effusion in the left knee joint—suppurative arthritis. The stump was swollen and tender.

Operation was performed. (i) The knee joint was aspirated, 60 cubic centimetres of purulent fluid being removed. (ii) The flaps were opened. The muscles were diffuent and pus was present. (iii) The mid-thigh amputation flaps were loosely sutured, two tubes being inserted. In the after-treatment two pints of blood were given by transfusion; 49,500 units of gas-gangrene antiserum were given; penicillin was given, 2,500 units by each tube twice a day for five days and 300,000 units parenterally.

On December 6 the patient was better. Culture from the knee joint consisted of *Staphylococcus aureus*, hæmolytic streptococci and diphtheroids. On December 25 the stump was healed. The patient was on crutches. The chest was clear and the breath was inoffensive after induced coughing. Neither sputum nor cough was present. On January 10 no abscess was apparent, the lung fields now appearing clear.

Gas-gangrene antiserum failed in prophylaxis. In spite of penicillin therapy this man developed bilateral clostridial lung abscesses which resolved under treatment, to be followed by a flare-up of the disease in the amputation stump and suppurative arthritis of the knee joint, long after the local focus appeared to be under control. Recovery was rapid after further amputation.

Discussion.

There was only one death in this series of 33 cases of gas gangrene. In a previous series of 25 cases dealt with by the writer in pre-penicillin days, the mortality was 35%. Such cases were almost invariably the most severe fulminating type, recognized twelve to twenty-four hours after infliction of a wound, with damage to major blood vessels. Amputation was usually performed.

As a group the present series was of a lower grade of severity, but there were ten fulminating cases, comparable in every way with those seen in forward areas. The disease was recognized after a longer interval (four to five days) and major vascular lesions were few (four cases). The general resistance of the patients would, therefore, have been better and the virulence of the infection might well have been modified by prophylactic measures (the use of serum, sulphonamide or penicillin).

In all cases the patients were given a combined form of treatment—surgery; penicillin, given locally and parenterally; blood transfusions; gas-gangrene antiserum; and sulphathiazole. It is therefore very difficult to assess the value of any single factor. It is not justifiable, in the state of present knowledge, to withhold any worthwhile form of treatment in such a serious condition.

Mortality.

The single death occurred in a case of fulminating clostridial myositis with open fracture of the femur and perforating wounds of the rectum. Death resulted from chronic sepsis two months after the patient's admission to hospital.

CASE VII.—Private G. suffered from a shell wound from a high explosive. He had an open fracture of the left femur and a fracture of the right ischium. He also had a perforating wound of the rectum and gas gangrene of the left thigh.

The patient was wounded on September 6 and operation was performed at a field surgical unit eleven hours later. Gross shattering of the upper third of the femur

was found. Loose bone fragments and dirt were removed. No foreign body was found. The wound was excised and plaster of Paris was applied; 99,000 units of gas-gangrene antiserum was given and an oral course of sulphonamide was begun.

On September 8 he was admitted to an orthopaedic centre attached to a general hospital. His general condition was poor. He looked "toxic". His temperature was 100.4° F. and his pulse rate was 120. Crepitus was present in the left thigh. Operation was performed on the left thigh. The *vastus lateralis* and *rectus femoris* muscles were necrotic and crepitant. A grossly comminuted fracture of the great trochanter was present with a foul-smelling discharge at the fracture line. He was seen by the writer in consultation with an orthopaedic surgeon (Major R. J. B. McEwan).

Rectal examination revealed a perforating wound of the lower part of the rectum. A foreign body was palpated in the right buttock. A comminuted fracture of the right ischial tuberosity was present. Excision of the *vastus lateralis* and the *rectus femoris* was performed by Major McEwan. A metallic foreign body was removed from the right buttock and a left inguinal colostomy was performed by the writer. The wounds were left widely open with "Vaseline" gauze drains. Retroperitoneal infection was present in the pelvic mesocolon. The general peritoneal cavity was not involved.

In the after-treatment three pints of fresh blood and 132,000 units of gas-gangrene antiserum were given by intravenous injection and a ten-days parenteral course of penicillin (1,320,000 units) was also given.

On September 9 the patient's general condition was improved. No spread of infection had occurred. Gas-gangrene antiserum, 66,000 units, was given. In an aerobic culture coliform organisms and diphtheroids were grown and in an anaerobic culture clostridia and Gram-positive cocci in chains were grown.

On September 10 the patient's general condition was poor. His temperature was 105° F. and his pulse rate was 140 per minute. The wounds were dressed. No spread of gas infection was discovered, but the fracture site was severely infected from the rectum. Three tubes were inserted. A routine local course of penicillin was given. On September 12 the patient's condition was still poor. A course of 30 grammes of sulphathiazole was given. On September 18 the wounds were dressed. Gas infection appeared to be under control, but the fracture site was pouring pus. It was thought that an infection of the hip joint was present.

On September 21 operation was performed, the left hip being disarticulated by Major McEwan. A grossly infected comminuted fracture of the upper end of the femur was found to extend into the hip joint. Three pints of blood were given. On September 28 severe secondary hæmorrhage occurred, bleeding taking place from the track into the rectum. The wound was packed and four pints of blood were given by transfusion.

On October 3 the pack was removed. The wounds were cleaner, but from this time onwards the patient's condition gradually deteriorated. The infection of the right buttock and pelvic tissues could not be brought under control and on October 28 the patient died.

The gas-gangrene infection seemed to be completely controlled after a few hours, but the infection of the fracture sites and pelvic tissues was well established when the patient was first seen and treatment failed to deal with this. The rectal lesion was not recognized at the original operation and the case presents a further example of the necessity for careful examination of the pelvis in all injuries of the upper part of the thigh and buttocks.

Amputations.

Five amputations were performed. This compares very favourably with previous experience. At times amputation is imperative. It is the logical method of removing the focus of infection.

A case of fulminating bilateral gas gangrene of the lower limbs from pre-penicillin field surgical unit days in Tunisia illustrates this point very well.

Private H., a stretcher-bearer in the Royal Army Medical Corps, was wounded by a mortar bomb and sustained open comminuted fractures of his left tibia and fibula and his right *os calcis*.

Five hours after the injury he reached the forward surgical unit, which was sited in a railway tunnel at Sedjenane in Tunisia. He presented a picture of profound "shock", which did not respond to the usual methods of resuscitation. After a short time it became clear from his pain and the local signs that he had fulminating gas gangrene of the left leg.

A mid-thigh amputation was performed, followed by blood transfusion and the administration of sulphapyridine soluble (the only sulphonamide suitable for parenteral use then available), gas-gangrene antiserum *et cetera*, and after a few hours his general condition began to improve sufficiently to justify hopes of his survival. Next morning, however, he complained of severe pain in the other limb and it was obvious from the cold, mottled foot with skin blebs filled with brownish fluid that he had gas gangrene there as well.

His condition deteriorated so rapidly that preparations for operation were suspended temporarily, as the outlook appeared to be hopeless. Blood transfusion was continued, however, and after a time operation was considered feasible.

In view of the fact that he already had a mid-thigh operation, it was decided to risk a below-knee amputation and this was performed—the flaps showing the brownish serous exudate of clostridial cellulitis. After a stormy few days his recovery was complete and he was evacuated to the base and eventually to the United Kingdom.

Without amputation this patient with bilateral fulminating gas gangrene most certainly would have died.

As time went on, a deliberately conservative policy with regard to amputation was followed, and it is considered that thereby limbs were saved. Three such cases are set out in detail (numbers XI, XII, XVII).

In Case XI the patient had fulminating gas gangrene of the right hand with oedema up to the elbow and an above-elbow amputation appeared to be unavoidable. He left hospital with the loss of thumb and index finger and some movement in the remaining digits.

In Case XII the patient had already had a mid-thigh amputation and developed fulminating gas gangrene in the thigh and leg of the remaining limb, which had sustained an open fracture of the tibia and fibula and multiple penetrating wounds of the thigh. The wounds were all healed and the fracture united ten weeks after injury.

Case XVII was that of a German prisoner of war with fulminating gas gangrene of the leg and thigh reaching to the abdominal wall. The outlook appeared to be quite hopeless, as he was almost moribund. An above-knee amputation, through obviously infected muscles, was performed as a last resort, but the toxæmia was at once brought under control and the infection became localized.

In several of the other cases amputation was very seriously considered, but results vindicated a waiting policy.

CASE XI.—Private E. suffered from gas gangrene of the right hand. On September 29 he sustained gross laceration of the right hand with dislocation of the wrist joint and multiple fractures of the carpal bones when a truck was blown up by a mine. It was thought that his maxilla was fractured. He was treated at a forward maxillo-facial unit sixteen hours after the injury.

On October 4 he was admitted to a general hospital. His general condition was fair. He had severe pain in the right hand. His temperature was 101° F. and his pulse rate was 110 per minute. At operation the whole of the right hand was found to be grossly swollen. There was a large flap of almost the whole of the skin of the palm, torn off with its base distally. Compound dislocation of the mid-carpus, the wrist joint and thumb and fracture of the second metacarpal bone were present, with extensive laceration of the thenar muscles. The whole area was grossly infected and malodorous. The forearm was swollen and tense up to the elbow. Gas gangrene was present. The patient was seen in consultation with a surgical colleague, who considered upper arm amputation advisable. After deliberation it was decided to attempt conservative treatment, as it was the right hand. Limited excision of necrotic tissue was performed and four penicillin tubes were inserted. A plaster of Paris splint was applied and ten grammes of sulphonamide were used locally.

In the after-treatment the patient received a blood transfusion of two pints, 49,500 units of gas-gangrene antiserum, 1,500 units of penicillin every three hours by each tube, and a full parenteral course as well as a course of sulphathiazole. An anaerobic culture of clostridia was obtained. On October 5 the patient was very drowsy and extremely ill. His temperature was 103° F. and his pulse rate 140. On October 6 he was better, but still had severe pain in the hand and forearm. At operation the thenar muscles, which were gangrenous and dead, were excised. The flexor tendons were exposed but intact. The thumb was partially gangrenous, but was preserved meanwhile.

The infection appeared to be localizing, so amputation was again postponed. Four penicillin tubes were inserted. The local and parenteral use of penicillin and the administration of gas-gangrene antiserum and sulphathiazole were continued.

On October 7 the patient was not so well and was more drowsy. It was decided to wait only a few hours before amputation. On October 8 the patient's condition was much improved and he had less pain.

On October 13 operation was performed. The thumb and index flexor tendons were sloughing. The thumb and index finger were amputated. Swelling of the hand was much less.

On November 20 Thiersch grafts were applied to the hand, and on December 5 the patient was evacuated to the United Kingdom with the wounds completely healed. The carpus was fixed, but a little movement was present in the remaining fingers.

This was a case of fulminating gas gangrene of the right hand in which a considerable portion of the limb was saved by conservative treatment. The loss of the thumb was unfortunately inevitable, but further amputation is unlikely, as the patient had some function of the fingers. The sudden dramatic improvement on the third day demarcated the point at which the toxæmia was brought under control. The total therapy included 300,000 units of gas-gangrene antiserum, 150,000 units of penicillin used locally and 1,000,000 units given parenterally, and 25 grammes of sulphathiazole.

CASE XII.—Private T. suffered from a shell wound. He had a traumatic amputation of the left leg, an open fracture of the right tibia and fibula, multiple penetrating wounds of the right thigh, and fulminating gas gangrene of the right leg and thigh. He was wounded on September 30 and operation was performed at a field surgical unit eighteen hours later. A mid-thigh amputation was performed on the left side. Multiple incisions were made in the right thigh and leg, and plaster of Paris was applied; three doses of 49,500 units of gas-gangrene antiserum and 300,000 units of penicillin were given parenterally.

On October 5 he was admitted to a general hospital. His general condition was poor. He had severe pain in the right thigh and leg and crepitus was present up to the inguinal ligament. His temperature was 105° F. and his pulse rate 140 per minute.

Operation was performed. The amputation stump, which was clean, was sutured, ten grammes of sulphonamide powder being used locally and two penicillin tubes being inserted. Multiple penetrating wounds were present in the middle and upper parts of the right thigh, and the whole thigh was swollen and indurated. Crepitus was present up to the anterior abdominal wall. Multiple incisions were made. Several large metallic foreign bodies were removed from abscess cavities. Muscle was necrotic. Three penicillin tubes were inserted. Open fracture of the upper third of the right tibia and fibula was present. The wound was tense with sero-sanious discharge and was enlarged. Two long lateral incisions were made in the calf. Two penicillin tubes were inserted.

In the after-treatment 1,500 units of penicillin were given per tube every three hours for 72 hours and then twice a day for three days; 500,000 units were given parenterally; 25 grammes of sulphathiazole were given, and two pints of blood by transfusion. Clostridia were grown in anaerobic culture from the right thigh and right leg. The wound of the left thigh was sterile.

On October 6 the patient felt better. He had no pain. His temperature was 103° F. and his pulse rate 120 per minute. On October 12 sutures were removed from the left thigh, which was healed. In the right leg and thigh all wounds had settled down and necrotic sloughs were separating.

On October 16 some greyish slough was present between the bone ends of the right leg. The fracture was reduced. One tube was inserted and the wound was left open. The lateral wounds were sutured. In the right thigh three large wounds were sutured. Three tubes were inserted. An abscess on the outer side of the thigh was drained. A foreign body was removed and one tube was inserted.

In the after-treatment, 1,500 units of penicillin were given per tube twice a day for five days; 300,000 units were given parenterally; two pints of blood were given by transfusion. No culture could be grown.

On October 27 all the wounds were healing. A wide sinus was present to the fracture site with some purulent discharge. Plaster of Paris was applied. On December 8 all the wounds had healed. The fracture was closed and union was established. The patient was evacuated to the United Kingdom.

The total therapy included 230,000 units of penicillin given locally and 800,000 units given parenterally, as well as 148,500 units of gas-gangrene antiserum.

This case was one of fulminating gas gangrene in which both penicillin and gas-gangrene antiserum failed in prophylaxis.

By conservative treatment the remaining limb was saved, and in any case amputation was out of the question, as the infection had reached the abdominal wall. The wounds were all healed and the fracture united 69 days after infliction of the wound.

CASE XVII.—A German prisoner of war had gas gangrene of the leg and thigh. On November 7 he had sustained a high-explosive shell wound of the left thigh and leg.

On November 19 operation was performed at a forward surgical centre. Devitalized muscle was excised; it was thought that possibly the femoral vessels were injured. Penicillin powder was instilled and "Vaseline" gauze and a splint were applied.

On November 23 the patient was admitted to a general hospital. His general condition was poor and he looked "toxic". On November 24 a small secondary hæmorrhage occurred from the thigh wound. The patient was taken to the operating theatre. A theatre dressing was applied. Hæmorrhage had ceased. The patient's condition was too poor for an anæsthetic to be given. Gas gangrene appeared to be present, but not frankly so. One tube was laid in the wound and 49,500 units of gas-gangrene antiserum were given. Routine local penicillin therapy was used. A course of sulphathiazole was given and two pints of blood were given by transfusion. Clostridia were not grown in culture.

On November 29 the toes were blue and the foot was painful. An abscess of the calf was incised and foul-smelling pus was evacuated. Two tubes were inserted. On December 2 the patient's condition had suddenly greatly deteriorated. His foot was cold and blue. His temperature was 103° F. and his pulse rate 120 per minute. One pint of blood and 66,000 units of gas-gangrene antiserum were given. On December 3 the patient's condition was much worse. Crepitus was present up to the inguinal ligament. His temperature was 103° F. and his pulse rate was 140 per minute. Upper thigh amputation was performed. The limb was cold and mottled up to the knee joint. At the amputation site there was the tell-tale brownish fluid in the flaps, and the muscles were tensely swollen and greyish, but contractile. Two penicillin tubes were inserted. The flaps were left open. Ten grammes of sulphonamide were used locally. A parenteral course of penicillin was begun, and 49,500 units of gas-gangrene antiserum were given. Two pints of blood were given by transfusion.

On December 5 the patient's general condition was much improved. Clostridia were grown in anaerobic culture.

On December 10 the stump was dirty and the hamstrings and portion of the adductors were putrescent and semi-fluid. They were wiped away up to their origins. A proflavine emulsion dressing was applied. On January 2 secondary suture of the stump was performed. The patient's general condition was excellent.

This was a case of fulminating gas gangrene developing over three weeks after the patient was wounded. Penicillin was temporarily in short supply so could not be given in the early stages, except locally.

When the disease set in, its progress was so rapid that the outlook appeared hopeless, the lower limb was lifeless to the knee joint and there was crepitation up to the abdominal wall. As a higher amputation was out of the question, the limb was removed through an obviously infected area, proved by the subsequent separation of the diffuent muscles in the stump. Penicillin applied locally failed in prophylaxis.

The total therapy included 148,000 units of gas-gangrene antiserum, 30,000 units of penicillin used locally and 500,000 units given parenterally, and 40 grammes of sulphathiazole.

Gas-Gangrene Antiserum.

Prophylaxis.—Fifteen patients received prophylactic doses of gas-gangrene antiserum, ranging from 16,500 to 150,000 units per case. Nevertheless, severe gas gangrene developed. Thus the value of serum in prophylaxis at least appears to be doubtful.

Treatment.—Every patient received antiserum. A dose of 49,500 units was repeated on successive days, as stated above. This method of administration was based on the reputed antitoxic action of the serum, and although this may be disputed, one did not feel justified in omitting it.

Role of Chemotherapy.

Penicillin.

Prophylaxis.—Twelve patients had local applications of penicillin powder at the primary operation. Two patients had local instillations of 35,000 units of sodium penicillin solution. Ten patients had parenteral courses of 100,000 to 1,450,000 units. In spite of this treatment, all developed gas gangrene. In five of the latter cases (XII, XXV, XXVI, XXIX, XXXII) the infections were among the most severe in the series.

Treatment.—Local instillation by tubes supplemented by parenteral injections was the routine method. The average dosage was 17,500 units per tube, spread over five days, with 300,000 to 500,000 units given intramuscularly. These doses were increased in a few cases.

It is extremely difficult to assess the role of chemotherapy in the treatment of gas gangrene. Penicillin appears to be of little value in prophylaxis in the manner given. *In vitro* tests show that penicillin is bacteriostatic for all clostridia, and yet in some cases organisms persisted locally long after the toxemia had subsided. Perhaps the organisms change to a resistant form. Unfortunately it was not possible to carry out full sensitivity tests. Perhaps the local and parenteral penicillin therapy, together with sulphathiazole, produces a synergic combination more effective than either drug alone. There is some experimental evidence that this may be so (Bigger,⁶ 1944). Perhaps by destroying the cocci present penicillin prevents the formation of the medium of devitalized tissue, on which the growth of clostridia depends.

Whatever the true explanation may be, it was abundantly clear that the patients recovered dramatically and gave far less cause for anxiety than previously. Thus, on clinical observations, the value of penicillin was unquestionable, but the true explanation of its mode of action must be awaited.

Fulminating gas gangrene involving the buttock, upper part of the thigh, abdominal wall and shoulder girdle provides the test case. In these situations radical surgery is not possible and hope must lie with chemotherapy. Three only of the cases (XII, VII, XXVI) approximated to this type.

PENICILLIN IN SECONDARY HÆMORRHAGE AND INFECTED ARTERIAL HÆMATOMATA.

This final section is included to demonstrate the value of penicillin in one of the most serious emergencies met with by the war surgeon—the control of secondary hæmorrhage.

Severe damage to blood vessels will be revealed at the primary operation and will have received appropriate treatment; but less extensive injury may result in partial division of a vessel or in bruising of its wall. In the case of veins, little harm usually results, but in arteries above medium calibre there may form some type of arterio-venous fistula or an arterial hæmatoma which eventually develops into a traumatic aneurysm.

A detailed revision of the subject of aneurysms is beyond the scope of this paper. Non-urgent cases are dealt with in centres with special experience. This discussion will, therefore, be confined to cases of secondary hæmorrhage and arterial hæmatomata demanding urgent operation. Most of the cases

met with have been in infected penetrating wounds with retained foreign bodies.

When a vessel has been incompletely divided, the hole is at first plugged with blood and it is not until the arterial blood pressure recovers that a leak occurs and an arterial hæmatoma gradually forms. If such a process is slow, a traumatic aneurysm develops, and this does not call for immediate surgery except for complications of rupture or pressure on important structures.

A similar process may take place when the vessel wall has been bruised, especially if there is local infection. The affected area gives way and either forms a slowly enlarging aneurysm or reveals itself by secondary hæmorrhage. The onset is thus dramatic and unpredictable. Treatment must be prompt if life or limb is to be saved, and operations have frequently to be undertaken in areas which are already badly infected. The risks are obvious and any help that penicillin can give in the control of infection may be just sufficient to tide the patient over a serious crisis.

During one year 15 serious cases of secondary hæmorrhage or ruptured arterial hæmatomata have been dealt with, involving the popliteal, posterior tibial, femoral, gluteal, axillary and brachial arteries. The four typical case reports which follow illustrate the problems involved and the part played by penicillin.

Sergeant W., on April 25, 1944, received a shell wound of the right buttock and had right sciatic palsy. He was operated on at a casualty clearing station twelve hours later. The wound was excised. Penicillin powder was used and a "Vaseline" gauze dressing was applied.

On April 28 he was admitted to a general hospital. His condition was satisfactory. Right sciatic palsy was present, and X-ray examination showed numerous small metallic foreign bodies in the right buttock. On April 29 operation was performed, delayed primary suture of several penetrating wounds of the buttock being carried out. Two penicillin tubes were inserted. In the after-treatment 15,000 units of sodium penicillin per tube were used.

On May 8 the patient complained of tightness and pain in the right buttock. The sutures were removed. The buttock was tense and œdematous, especially the upper outer quadrant. On May 9 the wound was opened up. Slight oozing occurred. No pus was found. There was no evidence of hæmatoma. The muscle was œdematous. Light packing with proflavine emulsion was undertaken; 49,500 units of gas-gangrene antiserum were given. On May 12 the packing was removed. The wound was discharging pus. (*Staphylococcus aureus* was recovered in culture.)

On May 14 severe secondary hæmorrhage occurred from the right buttock. The patient was exsanguinated. He was given three pints of blood followed by one pint of plasma. Laparotomy was performed. The internal iliac vessels on the right side were ligated through a right rectus-splitting incision. The buttock wound was explored. Clot was turned out. Hæmorrhage was under control. The whole buttock was tense and boggy. The wound was lightly packed with proflavine emulsion. In the after-treatment 500,000 units of sodium penicillin were given parenterally.

From May 15 to 18 the patient was gravely ill. He was given two pints of blood. On May 19 he was better. The wounds were clean and the œdema of tissues had almost gone. No further hæmorrhage occurred. On May 24 the sutures were removed. The abdominal wound was healed. The buttock wound was discharging pus. The patient was still very pale. The hæmoglobin value was 70%; two pints of blood were given by transfusion. On June 6 the patient was improving slowly. The hæmoglobin value was still 70%. The buttock wound was healing. On June 10 gross hæmorrhage occurred from the buttock. The patient was exsanguinated. The wound was packed. Four pints of blood were given. A further course of 500,000 units of sodium penicillin was commenced.

On June 12 the patient's condition had improved, but he was still very weak and pale. Operation was performed. First of all provisional ligation of the common femoral artery was carried out under local anaesthesia. Then general anaesthesia was induced. A direct approach was made to the superior gluteal vessels through an oblique buttock incision. The tissues of the buttock were fibrotic and matted together. The circulation was controlled by pressure on the abdominal aorta. The clot was turned out. The bleeding point in the superior gluteal artery at the great sciatic notch was secured and sutured. The wound was closed. Three penicillin tubes were inserted.

In the after-treatment, 17,500 units of sodium penicillin per tube were given; 500,000 units were given parenterally. Two pints of blood were given by transfusion.

On June 24 the wounds were healed. The general condition of the patient had dramatically improved. He was putting on weight and eating well. He had no further symptoms. On July 10 he was evacuated to the United Kingdom. Sciatic palsy was still present.

This is a very instructive case. It demonstrates important points in the management of gluteal aneurysms. Such aneurysms are extremely difficult to deal with by a direct approach, as it is not easy to obtain proximal control of the circulation, and besides, access is hindered by the boggy nature of the damaged tissues in an infected field. Ligation of the internal iliac artery in continuity has been successful in four similar personal cases, but in this instance a collateral circulation was reestablished within a month and a second severe haemorrhage exsanguinated an already debilitated patient. Slipping of the ligatures on the internal iliac artery was unlikely, as it had been doubly tied with strong silk. Direct approach was the only alternative, and control was obtained with surprising ease by direct aortic compression. This manoeuvre was rendered easier by the thinness of the abdominal wall following an already prolonged illness.

The recovery of this patient must be due in no small measure to penicillin, as the infection remained localized and as soon as the vascular lesion was effectively controlled recovery was rapid and complete apart from the sciatic palsy.

Sergeant B. received a high-explosive shell wound of the right buttock on June 12. He was operated on at a field surgical unit twenty hours later. The wounds were excised. Penicillin powder was used and a "Vaseline" gauze dressing was applied.

One June 18 he was admitted to a general hospital. His condition was fair. X-ray examination showed a retained metallic foreign body. The wound was discharging and was unfit for suture. The foreign body was removed. The wound was not sutured. One penicillin tube was inserted. On June 22 gross secondary haemorrhage occurred from the right buttock. Four pints of blood were given. The wound was packed. The patient's general condition was very poor. On June 25 the packing was removed. Haemorrhage recurred. The wound was repacked and three pints of blood were given. A parenteral course of 500,000 units of penicillin was begun. The patient's general condition was poor.

On June 26 oozing of blood and pus occurred around the packing. Cough was present. Examination of the chest showed scattered moist sounds in both lungs. On June 27 the oozing was increasing, although the wound was firmly packed. The patient's general condition was deteriorating. Two pints of blood were given. Laparotomy was performed and the right internal iliac artery was ligated with number 5 silk. The patient collapsed on the table and his heart stopped, but recommenced beating after cardiac massage and the injection of "Coramine" *et cetera*.

On June 28 the patient's condition was poor. He was coughing up a copious amount of purulent sputum. X-ray examination showed two abscesses, one and a half inches in diameter, in the upper lobe of the right lung, and one abscess, one inch in diameter, in the upper lobe of the left lung. Penicillin therapy was continued.

On July 6 the patient's general condition had greatly improved. The buttock wound was healing. He was eating and sleeping well. On July 8 he was transferred to a chest centre, where the lung abscesses were treated by posture and aspiration with local penicillin replacement. On August 26 he was evacuated to the United Kingdom. His chest was clear, his buttock was completely healed and his general condition was excellent. The total penicillin therapy was 1,250,000 units.

If the parenteral course of penicillin had been commenced at the first sign of haemorrhage the pyaemic abscesses might not have occurred. Packing the infected wound probably initiated the pyaemia and the patient's condition became desperate. The wound was heavily infected and the haemorrhage was not under control. A major operation had to be undertaken in a gravely ill, anaemic patient with multiple lung abscesses, and it is difficult to believe that he could have survived without penicillin.

Lance-Corporal H. sustained a high-explosive shell wound of the right shoulder, arm and thigh on September 6. He was operated on at a field surgical unit twelve hours later. The wounds were excised, penicillin powder was instilled, and a "Vaseline" gauze dressing was applied. A thoraco-brachial cast was fitted.

On September 9 he was admitted to a general hospital. His condition was fair. X-ray examination showed a fracture of the scapula and several retained metallic foreign bodies. The haemoglobin value was 70%. One pint of blood was given. On September 11 a small wound of the right infraclavicular region was sutured; one penicillin tube was inserted. A three-inch dirty wound of the supraspinous fossa was not sutured; one penicillin tube was inserted. Six small wounds of the right arm and thigh were sutured. Penicillin powder was applied. Attempts to grow cultures from the wounds failed.

In the after-treatment 17,500 units of sodium penicillin were given per tube and 150,000 units were given parenterally.

On September 21 the sutures were removed. All the wounds had healed, except that in the supraspinous fossa. On September 30 cellulitis of the right scapular region was present. On October 2 an incision was made and a foreign body was removed from an abscess cavity over the upper dorsal spine. A proflavine emulsion wick was inserted.

On October 5 the right forearm and hand were swollen. A tense and expansile swelling was present in the right axilla. No thrill was present, but a soft systolic bruit was loudest over the inner end of the clavicle. No evidence of a nerve lesion was found. A developing traumatic aneurysm of the first part of the axillary artery was diagnosed. The arm was elevated on a pillow. On October 8 slight anaesthesia was present over the ulnar nerve distribution in the hand. On October 9 the swelling was not increasing in size, but the small muscles of the hand were now paralysed.

On October 12 the aneurysm was increasing in size, but oedema of the arm had settled down. The systolic and diastolic blood pressure in the left arm was 118 and 70 millimetres of mercury, and in the right 78 and 70 millimetres. The haemoglobin value was 70%. The swelling involved the whole of the axilla, passing beneath the clavicle. Well-developed ulnar nerve palsy with added loss of sensation was present over the thenar eminence. Some purulent discharge came from the unhealed shoulder wound. On October 13 a transfusion of two pints of blood was given.

On October 14 the first part of the axillary artery was ligated and the damaged segment was excised. The traumatic aneurysm, which was the size of a large grapefruit, involved the upper part of the axilla. There was a hole six to eight millimetres in diameter on the medial side of the first part of the axillary artery, just distal to the outer edge of the first rib. A small metallic foreign body was found in an abscess cavity in the wall of the aneurysm. The steps of the operation were as follows: (i) Provisional ligation of the subclavian vessels was carried out, the scapular anastomosis being carefully preserved. (ii) The Fiolle-Deknas approach to the upper part of the axilla was adopted, the clavicle being divided towards the sternal end with a Gigli saw. (iii) The sac was opened and the clot turned out, the hole in the artery being thus exposed. The first part of the axillary artery was ligated between ligatures of number 5 twisted silk. A segment one inch long was removed. A metallic foreign body was removed. (iv) The clavicle was wired. The wound was closed in layers. Three penicillin tubes and a dependent rubber drain were inserted. The hand was cold at the end of the operation.

In the after-treatment the arm was exposed to room temperature at chest level. Three pints of blood were given, and also 15,000 units of sodium penicillin per tube and 500,000 units parenterally.

On October 15 the patient's general condition was good. The tips of the fingers were cold, but good movement was present. It was thought that the radial pulse could be felt. On October 22 the sutures were removed. The wounds were almost healed. A small amount of discharge came from the tube holes. The ulnar palsy was slightly improved. The hand was warm and a radial pulse was present. On November 30 the patient's general condition was excellent. The intrinsic muscles of the hand were still paralysed. Early trophic changes were present in the finger tips. The wounds were healed. The clavicle was united. The patient was marked for long-term evacuation to the United Kingdom.

This was an emergency operation in an infected field with a satisfactory immediate result. Penicillin simplified the post-operative course by effectively controlling the inevitable flare-up of the local infection.

Private B. was wounded with a high-explosive shell fragment on September 4. He had a traumatic amputation of the right leg and a penetrating wound of the right axilla. He was operated on at a field surgical unit ten hours later. The lower part of the leg was amputated and wound excision was carried out. Penicillin powder was instilled and a "Vaseline" gauze dressing was applied. Three pints of blood were given.

On September 8 he was admitted to a general hospital, and on September 9 delayed primary suture of the amputation stump was carried out. Two penicillin tubes were inserted. The axillary wound, which was infected, was dressed.

On September 9 the patient complained of severe pain in the amputation stump. Severe hæmorrhage occurred through the dressing. The peroneal vessels were ligated for secondary hæmorrhage. It was found that the peroneal vessels were bleeding freely, evidently owing to the slipping of ligatures. The flaps were œdematous; they were loosely sutured. Two penicillin tubes were inserted and three pints of blood were given.

In the after-treatment 15,000 units of sodium penicillin were given per tube and 300,000 units were given parenterally.

On September 12 the patient's condition was improving. His temperature was 100° F. On September 19 the sutures were removed. The stump was 60% healed. A proflavine dressing was applied and skin extension applied to the flaps.

On September 20 a warning hæmorrhage occurred from the axillary wound. A soft bruit was audible and what looked like an arterial hæmatoma was present. A firm bandage was applied. On September 23 the axillary wound was infected. Brisk hæmorrhage occurred. The wound was packed with proflavine gauze and a firm bandage was applied. A parenteral course of penicillin was commenced. The circulation in the hand was satisfactory. No evidence of a nerve lesion was found.

On September 24 no further hæmorrhage had occurred, but on September 27 severe hæmorrhage occurred from the axilla around the packing. The patient's condition was poor. Operation was decided on and three pints of blood were given. The second part of the axillary artery was ligated for traumatic aneurysm. There was a hole five millimetres in diameter in the medial aspect of the axillary artery with an aneurysmal sac the size of a small orange. The cavity and surrounding tissues were infected. (A culture of *Staphylococcus aureus* was obtained.) At operation the pack was removed. The subclavian vessels were controlled by digital pressure. The wound was rapidly opened up, the *pectoralis major* muscle being partially divided. Clot was evacuated and the hole in the artery exposed. The vessel was then freed, clamped and divided between ligatures. The wound was closed in layers. Two penicillin tubes were inserted and two pints of blood were given.

In the after-treatment 15,000 units of sodium penicillin were given per tube and 500,000 units were given parenterally. The limb was elevated to heart level at room temperature. On September 28 the fingers were warm and moved well. Subsequent progress was uneventful. Full movement and recovery of the radial pulse occurred within a few days. On October 14 all wounds had healed and the patient was evacuated to the United Kingdom.

This is a further example of the value of penicillin in controlling infection in a serious emergency. In this case proximal control of the circulation was fortunately secured by digital pressure. It is doubtful whether the patient would have survived a prolonged operation, as he had not yet fully recovered from the effects of the hæmorrhage from the amputation stump.

COMMENTARY.

The results obtained in the foregoing cases demonstrate the value of penicillin therapy in the control of infection in recent wounds. The cases cover a wide range and the methods laid down may well be applied to most wounds.

It is difficult to set down on paper the remarkable improvement in treatment that has occurred, but when the results obtained by the closed-plaster method are recalled, the real value of this new bacteriostatic is seen.

The problem of chronic sepsis still remains, but it has been reduced to small proportions. Hospital wards are no longer filled with the pale, wasted patients whose faces showed all too clearly the debilitating effects of prolonged sepsis and pain.

One of the most noticeable features of penicillin therapy is the remarkable change in the general condition of patients, which takes place within a few hours of the commencement of treatment. They feel well, eat well and sleep well, and pain quickly diminishes in intensity. The conditions for rapid healing are thus established early, as a balanced diet with a high protein content is soon tolerated. This lack of constitutional disturbance also encourages early movement, with consequent maintenance of muscle

tone and joint function. The work of the physiotherapist is thus made easier and mass ward exercises can be undertaken by cooperative patients competing actively with one another.

Penicillin appears to discourage the formation of fibrous tissue, and this materially assists the early return of full function, as scarring is minimal. For this reason, too, it is advisable to leave sutures a little longer than normal.

The importance of the early provision of skin cover has already been stressed, but it must be remembered that the deeper tissues require time to heal, as they are always more extensively traumatized than one would expect from the surface wound. Hence there must be a prolonged period of rehabilitation with careful supervision for every severely wounded man, even though early skin closure has been achieved.

It would appear to be established that the majority of wounds can now be closed safely at an early stage, but a small proportion of failures remain. Such failures occur chiefly where the primary surgery has been at fault or tissue damage has been too extensive to permit early closure. It cannot be stressed too strongly that bacteriostatics are an adjunct to, and not a substitute for, careful surgery.

After the fundamental principles of surgery have been properly applied, bacteriostatics will provide that valuable margin of safety which will allow extra risks to be taken. The value of the local introduction of a bacteriostatic at the primary operation must now be recognized, but it would be desirable to commence full therapy as soon as possible after infliction of the wound. The parenteral method of frequently repeated injections is unsuitable for patients in transit and a better method must be found. It has been suggested that the use of penicillin in an oily emulsion delays absorption and perhaps a single large daily dose thus administered would protect the patient until he reached the base hospital. The production of a form suitable for oral administration would greatly simplify the problem.

Although it has been emphasized that bacteriological control is unnecessary during the early stages of treatment, examination of the wound flora is very necessary in cases of failure. In all such cases the sensitivity of the organisms and the activity of the batch of penicillin used should be tested.

The role of penicillin in chronic sepsis is not yet established and the methods at present in use are not satisfactory. It is suggested that the use of the newer acridine derivatives, together with more prolonged courses of penicillin, given both locally and parenterally, will be the most promising line for future treatment to follow. The strength of the solution used locally might be increased to 1,000 to 1,500 units per cubic centimetre, as it is unwise to allow large quantities of fluid to pool in the tissues. The closed-plaster method should not be revived except as a last resort.

In this paper emphasis has been placed on the local administration of penicillin, but at this stage in our experience modes of administration are under trial, and time alone will demonstrate the correct method to be used for any particular case. The local method is not without its dangers, as it is almost impossible to prevent secondary infection with Gram-negative organisms. So far, little trouble has been experienced in fractures from such infection, but complications may well arise. When supplies of penicillin become more plentiful and cheaper, the parenteral method will probably be used more extensively, but local instillation will still have a place in certain cases in which high concentrations are required.

SUMMARY.

The results of local and parenteral penicillin therapy applied to recent war wounds are discussed.

1. The two-stage operation was applied to 509 cases of soft tissue wounds and 184 open fractures. Of 434 soft tissue wounds treated by delayed primary suture, 336 (77%) were completely healed in fourteen days. Only 39 cases (9.2%) were considered to be failures. In 75 soft tissue wounds treated by secondary or excision suture, results were almost as satisfactory. In a consecutive unselected series of 184 open fractures, complete suture could be carried out in 114, and 98 (86%) of these were closed within six weeks. The causes of failure are discussed, and examples are given of treatment adopted in such cases.

2. Thirty-three patients with gas gangrene were treated, with one death.

3. Detailed reports are given of four cases of secondary hemorrhage or infected arterial haematomata.

CONCLUSIONS.

Soft-Tissue Wounds.

1. The two-stage method of closure with the use of local penicillin therapy gives a high proportion of wounds healed in fourteen days.

2. Early efficient primary surgery and the local introduction of a bacteriostatic at the first operation are important contributory factors to the success of the procedure.

Open Fractures.

1. The two-stage operation is equally applicable to the closure of open fractures. Where complete skin cover can be obtained, most will be closed within six weeks.

2. Routine bacteriological examination is unnecessary in the assessment of suitability for wound closure. Clinical judgement will be sufficient.

3. The transformation from open to closed fractures promotes early union and speedy return to function.

Gas Gangrene.

Penicillin used prophylactically both locally and parenterally did not prevent the onset of gas gangrene. Whilst on clinical grounds penicillin with sulphathiazole appears to be of extreme value in the treatment of this condition, its true role cannot be evaluated on the evidence available. Early efficient surgery remains the most important factor in the prophylaxis and treatment of clostridial infection.

Emergency Operations in Infected Fields.

Penicillin is of extreme value in the control of infection when emergency operations must be undertaken in such conditions as secondary hemorrhage or infected arterial haematomata.

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THE CLOSURE OF COLOSTOMY OPENINGS.¹

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FEW common operations in surgery fail in their purpose more often than does that for closure of a colostomy. All too frequently the attempt is followed by a faecal leakage, which may continue for many weeks before it ceases spontaneously, or may require one or more additional operations for its control. Not only is the procedure regarded by most surgeons as being a good deal less satisfactory than it should be, but the cause of a failed closure is frequently not obvious.

On the other hand, the wound heals in some instances without the least faecal discharge, although varying degrees of cellulitis of the surrounding tissues appear to be almost inevitable. Since these two groups clearly represent vastly different degrees of satisfaction from the viewpoint of both the surgeon and the patient, the subject is worthy of close consideration.

Temporary colostomies are now frequently required and may be seen in a wide variety of patients. Advances in the surgical treatment of carcinoma of the colon have led to widespread recognition of the value of exteriorization techniques and the principle of a proximal defunctioning colostomy prior to resection and anastomosis. In addition, volvulus of the sigmoid loop may call for exteriorization, and temporary diversion of faeces is required in some large bowel inflammations, as well as in every case of gunshot wound of the rectum. Spontaneous closure cannot be relied upon to restore the continuity of the colon when the artificial anus has served its purpose. There are two reasons for this—the presence of the spur and the continuity between skin and mucous membrane. Spur crushing in itself will not usually be followed by complete closure, even after a long period of time, for the attachment of the mucous membrane to skin is in itself sufficient to maintain the fistulous opening. Thus closure by operation is required in almost every case.

An inquiry has been made into the frequency of failed closures in a series of eighty-seven consecutive cases, the details of which were taken from the records of a large public hospital. The probable causes of post-operative faecal leakage have been examined, together with the operative techniques employed.

THE FREQUENCY OF FAILED CLOSURE.

All cases in which operation was followed either temporarily or permanently by the discharge of faecal material from the wound are considered to be "failed closures". At times breaking down of the wound was associated with the discharge of purulent material only. This must be regarded as an unsatisfactory result, in that a longer period of hospitalization is required. But a more important aspect of such wound infection is that in many cases, before the pus collection finds its way to the outside skin, it is responsible for destruction of the suture line of the bowel itself and a faecal discharge results. For this reason some surgeons advocate delayed suture of the skin in all colostomy closures.

¹ Accepted for publication on January 3, 1946.

Table I shows that in 29 cases out of 87 (33·3%) closure was successful. In nearly all of these cases cellulitis was present around the wound for several days after the operation. When a discharge of pus occurred, without faeces, it usually continued for ten to fourteen days.

TABLE I.
Results in Eighty-seven Consecutive Cases.

Observation.	Number of Cases.
No discharge from wound (successful closure)	17
Pus only (successful closure)	12
Faeces temporarily (days to weeks)	33
Further operation or operations required before closure effected	14
Faeces still discharging when last seen	8
Deaths	3
Total	87

Of the three deaths, two were due to uncontrollable hæmorrhage associated with the application of an enterotome to the spur, and the third to peritonitis which followed intraperitoneal closure.

In one case the application of an enterotome was followed by an ileo-colic fistula.

OPERATIONS EMPLOYED.

Table II indicates the variations in technique which were used in this series, their numbers, and the proportions of successes and failures.

TABLE II.

Operation. ¹	Number of Times Performed.	Success.	Fæcal Leakage.
Subcutaneous closure. The skin only is brought together over the sutured bowel	54	7	47
Dissection of the abdominal wall and extraperitoneal closure of the colon	33	14	19
Intraperitoneal closure	13	8	5 (includes one death)
Suture of bowel and skin around enterotome	7	In two of these cases healing finally occurred. In five, further operation was required.	

¹ Total number of operations was 107.

It may be noted that: (a) In the second group the amount of dissection of the abdominal wall varied considerably. In some instances a complete dissection of all layers was performed, whereas in others the sutured bowel was placed beneath the external oblique muscle only. (b) A faecal discharging sinus was often treated by cauterization with silver nitrate followed in some cases by balloon pressure. This in itself did not seem to produce any beneficial results. (c) In one case of intraperitoneal closure death resulted from peritonitis. The fact that in four out of a total of thirteen cases in this group a faecal discharge developed along the path of a drainage tube further emphasizes the danger of this operation. (d) There were no cases in which delayed suture of the wound was performed. (e) The total number of

operations here considered (107) exceeds the number of patients because multiple operations were performed in 17 instances.

These figures seem to indicate that a layer dissection is more likely to produce a successful result than is subcutaneous closure. I believe that such is actually the case, other conditions being equal, because of certain benefits derived from the complete mobilization of the bowel which is obtained in the former operation. But factors other than the actual type of operation performed also exert a great influence in determining the outcome. Such factors are the adequacy of spur crushing, the absence of any obstruction beyond the colostomy, the preparation of the bowel edge for suture, and, finally, meticulous attention to inturning of the mucosal edges. It is impossible to assess from even carefully kept records the bearing which any or all of these influences may have had in a particular case. Consequently the above figures have a limited significance and can in themselves give only the broadest indication of the type of operation which is most likely to result in successful closure.

THE BOWEL BEYOND THE COLOSTOMY.

A careful review of the distal part of the colon is a necessary preliminary to colostomy closure. If a resection and anastomosis have been performed beyond the colostomy, a barium enema should be given to ascertain that no appreciable stricture formation is present. Still greater caution is necessary in the closure of colostomies which have been performed for the relief of inflammatory states. The fact that healing is complete in conditions such as radionecrotic ulcer or gunshot wound involving the rectum is usually easy to establish by sigmoidoscopic examination. But even when diverticulitis of the sigmoid has been quiescent for many years after the performance of a proximal colostomy, nevertheless a dangerously acute exacerbation may follow the operation of closure. The following chastening experience will illustrate this risk:

J.C., a male, aged forty-five years, had a left iliac colostomy performed ten years before because of diverticulitis of the sigmoid colon. The inflammatory state had completely subsided, the colostomy was functioning satisfactorily, and the patient appeared to be in perfect health. However, he was now very desirous of having the colostomy closed. The anus, which had not functioned for so long, would admit an examining finger only with difficulty, but was elastic. A barium enema was given and showed that, apart from several small diverticula, the bowel between the colostomy and the anus appeared normal and apparently capable of transmitting faeces. Abdominal examination revealed no mass or tenderness, so that the case appeared to be one in which the inflammatory process had subsided wholly. The spur was crushed and three weeks later the bowel was dissected free from the abdominal wall and closed extraperitoneally. Within a week faeces were being passed *per rectum* with the assistance of small glycerine enemata and the wound healed after a little cellulitis had subsided. The result appeared to be most satisfactory.

Several months later, however, the patient became desperately ill with acute diverticulitis and a reconstitution of the colostomy was necessary as a life-saving measure. The condition then subsided and has remained so until the present time.

It is clear that in this case a colostomy is a lifelong requirement.

SPUR CRUSHING.

Adequate crushing of the spur is a most important preliminary to successful closure of a colostomy. Although the enterotome was devised by Dupuytren⁽¹⁾ in 1832, Grieg Smith⁽²⁾ did not advocate preliminary spur crushing when he first described the operation of extraperitoneal closure in 1895. Moreover, at the end of the nineteenth century, Senn⁽³⁾ considered that with advances in abdominal surgery spur crushing would become obsolete. Yet today its position is unchallenged.

Many modifications of Dupuytren's original instrument have been devised, some differing considerably from his original model. Two instruments in common use are illustrated in Figure 1, the larger being shaped so as to permit crushing of the spur when a bridge of skin separates the two stomata. In both cases the blades may be taken apart for separate insertion into the bowel—a most necessary requirement.

But more important than the actual instrument used is preparatory suturing of the spur at the first operation. Neglect of this step may result in a loop of small intestine being caught, or mesentery being torn, with disastrous results. A study of the disposition of the afferent and efferent colostomy limbs should be made before an enterotome is applied. The surgeon may have performed the colostomy himself and thus be possessed of definite knowledge that the limbs of the loop have been sewn together in parallel fashion; on the other hand, he may know that the colostomy was originally regarded by another operator as one likely to be permanent and was left with diverging afferent and efferent limbs; finally, doubt may exist whether this was done or not. One must not assume that parallel suturing has been provided because a colostomy was regarded *ab initio* as being only a temporary measure. An examination with two gloved fingers will usually decide this question and should be performed in every case.

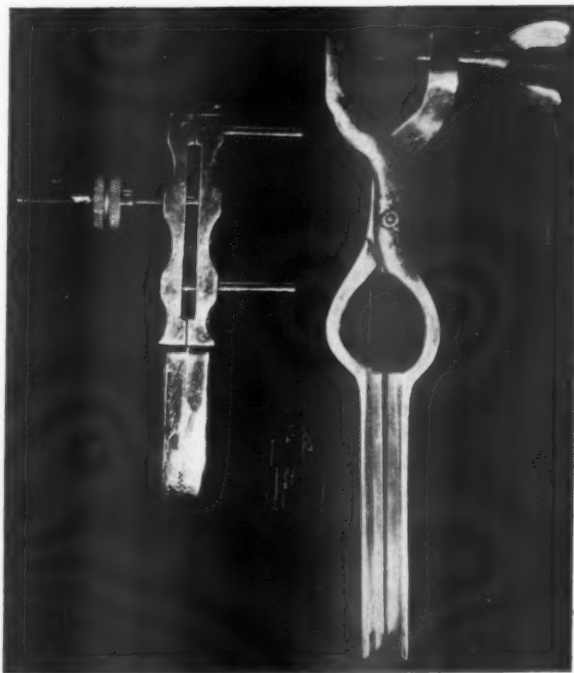


FIGURE 1. Two modern enterotomes. The overall measurement of the smaller is 5½ inches. The difference in the lengths of the blades illustrates the wide divergence of opinion which exists concerning the amount of spur which should be crushed. An intermediate length is more generally useful.

The risk of applying an enterotome is still frequently accepted when the limbs are found to be divergent. However, a wiser course in these cases is to perform an additional operation, such as the following, before the spur is crushed.

The colostomy openings are irrigated, cleansed and sealed off with waterproof adhesive and collodion. After a thorough skin preparation has been carried out, the abdomen is opened by an adjacent incision. The colostomy limbs are identified and stitched together in parallel fashion for a length of six inches by a continuous sero-muscular suture passing through the tæniæ. The suturing must extend as far as is possible towards the abdominal wall to avoid leaving a gap through which small intestine may become strangulated.

When a colonic resection has been performed by exteriorization technique, closure of the resulting colostomy should not be hurried. A considerable amount of oedema is present in and between the two loops of bowel, and such a condition is unsuitable for the application of an enterotome. In the average case an interval of six weeks or two months is required for this to subside and the patient may return to his home.

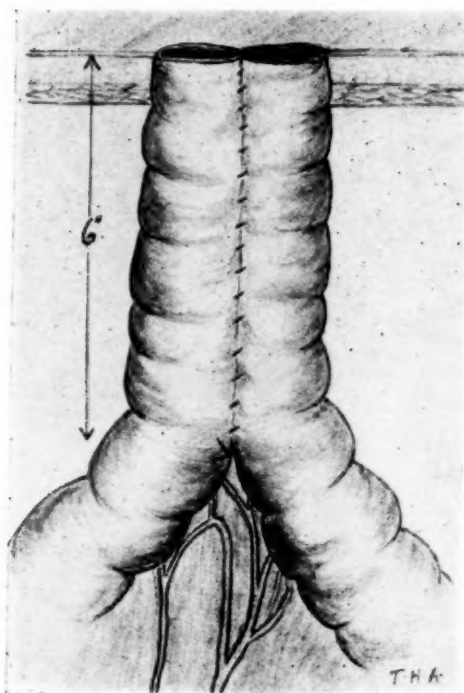


FIGURE 11A. Adequately sutured colostomy limbs.

The Application of the Enterotome.

The blades of the instrument should be guided into place separately with the assistance of a gloved forefinger, locked and very gradually tightened. The tightening is at first sufficient only to hold the instrument in place. Even this amount will usually cause some discomfort, since the pressure provides a stimulus similar to distension from within and is adequate to provoke sensations of pain. But these usually pass off gradually, causing little trouble.

Occasionally, however, pain is severe and continues for some time, accompanied perhaps by vomiting. If there is certainty that neither small intestine nor mesentery can lie between the jaws of the clamp, no cause for alarm is present and a watchful attitude is justifiable for two hours at least (Figure 11A). The position must then be reviewed in the light of lessening or increase

of the pain, and the decision made whether the clamp is to be removed or not. When doubt exists the clamp should be removed.

But when it is known that the colostomy limbs have not been sutured, the occurrence of these severe symptoms is reason for great anxiety. The clamp may well have gripped a loop of small intestine or the mesocolon and must be removed at once (Figure 11B).

The decision to proceed having been made, the clamp is tightened a little twice daily until the screw can be turned no further, resulting in severance of the spur in approximately five or six days. The patient must remain in bed. If the instrument is of such a type that long handles project at a right angle from the abdominal wall it should be firmly anchored in position between the safety pins of a binder. A large soup strainer can be used as an excellent means of further protection if it is inverted and attached to the binder so as to cover the projecting portion of the clamp. A bed cradle is necessary, but the handle of the enterotome should not be suspended from it. This is an unsafe practice which may result in the instrument being violently avulsed if the patient turns suddenly while asleep or in an irrational state. Bowel actions will occur as usual and the area around the blades may easily be cleansed with cotton-wool swabs. The clamp must never be removed by

pulling it away, but always by a cautious detachment of each blade in turn after the screw has been fully released. Any necrotic spur tissue which remains may then be gently broken down with a protected forefinger.

Spur crushing is by no means the minor procedure it is sometimes thought to be, especially if performed when a colostomy loop is present which has not been "paralleled". On the other hand, a survey of the literature reveals very few reports of disasters in its performance. Mayo⁴¹ in 1942 reported seven cases in which grave complications ensued. Briefly, these cases showed the following sequences of events:

Case I: Acute perforation of the bowel, general peritonitis, death.

Case II: Injury to the jejunum, jejuno-colic fistula, malnutrition, death.

Case III: Injury to the ileum, ileo-colic fistula, operation, recovery.

Case IV: Injury to the ileum, ileo-colic fistula, conservative management, recovery.

Case V: Injury to the ureter, uretero-sigmoid fistula, conservative management, recovery.

Case VI: Haemorrhage from spur, transfusion, recovery.

Case VII: Haemorrhage from spur, packing, recovery.

Unfortunately Mayo does not state with regard to any of these cases whether the limbs of the colostomies had been sutured together or not.

In the series of 87 cases reviewed in this paper, two deaths and one serious complication were associated with spur crushing.

Case I: A profuse secondary haemorrhage occurred three days after the clamp had been removed. There is no record of parallel suturing having been performed.

Case II: The patient pulled off the enterotome at night. This was followed by a fatal haemorrhage. The limbs had been sutured.

Case III: During the performance of Mikulicz's operation for a carcinoma of the transverse colon an ileo-transverse fistula followed the application of an enterotome to the spur of the transverse colostomy. The proximal and distal portions of the exteriorized loop had been sewn together, but the blades of the enterotome apparently extended beyond the limit of the suture and a loop of ileum was partly grasped within them. The fistula was later unpicked and the bowel repaired successfully.

One must conclude that serious and even fatal complications can result from this procedure. The likelihood of their occurrence is minimized if the afferent and efferent limbs of a colostomy loop are always sutured together before an enterotome is applied. Other factors which increase the margin of safety are careful application of the instrument itself, slow tightening of the screw, the keeping of the patient in bed, and constant supervision while the clamp is in place.

THE OPERATION FOR CLOSURE OF A COLOSTOMY.

Four ideals must be borne in mind in the planning of an operation for this purpose: (a) a successful closure, without faecal discharge in the post-

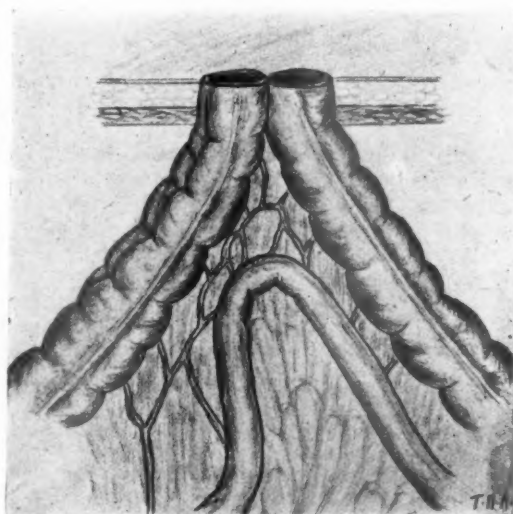


FIGURE 11B. An unsutured colostomy. The enterotome may cause haemorrhage from mesenteric vessels or may injure a loop of small intestine.

operative period; (b) no bowel obstruction from narrowing of the lumen at the site of closure; (c) no infection of the peritoneal cavity or abdominal wall; (d) a soundly reconstructed abdominal wall. All of these, with the possible exception of some infection of the abdominal wall, may be achieved with a considerable degree of certainty.

Intraperitoneal Closure.

There has been no serious advocacy of intraperitoneal resection and anastomosis as a means of closing a colostomy since the writings of Lockhart Mummery⁽¹⁷⁾ in 1917. This must be attributed to appreciation of the additional risk to the patient's life which is thereby incurred.

Closure of a colostomy is always an elective operation which is carried out only for the comfort and convenience of the patient. It therefore must be performed by that method which is above all else the safest. Lockhart Mummery, in recommending the intraperitoneal operation, put forward a number of arguments against extraperitoneal closure, but none appears to carry great weight:

(a) "It will fail unless the spur is well divided." This must be admitted, but satisfactory spur crushing is easy to accomplish.

(b) "It tends to leave a weak spot in the abdominal wall." This is true only if subcutaneous closure is performed—an operation which seems incomplete. If, however, the bowel is dissected free from all muscle layers, these may then be brought together separately after the stoma has been sutured and pushed inwards.

(c) "Since the peritoneum is often opened in one or two places, the whole operation may just as well be intraperitoneal." It is impossible to agree with this reasoning. The important point for consideration is surely the situation of the bowel suture line, relative to the peritoneal cavity, during the post-operative days, when leakage of faeces may occur.

(d) "It belongs to the category of lumbar colostomy and to the time when surgeons were afraid to open the abdominal cavity." This cannot be accepted.

Subcutaneous Closure.

Subcutaneous closure is an operation which is still very frequently performed. Lahey⁽¹⁸⁾ states that this procedure is quite sufficient when the patient has a thick, fat layer, and that the end results are quite as satisfactory as when the sutured bowel is buried beneath the muscle layers and fascia. Successful avoidance of post-operative faecal discharge admittedly depends chiefly on adequate elimination of the spur, absence of distal obstruction, and accurate inturning of the bowel edges—all of which factors will exert their influence irrespective of whether the bowel is placed in an extraperitoneal position or is allowed to remain subcutaneously situated. But the operation of subcutaneous closure presents certain disadvantages. Firstly, it leaves a weak spot in the abdominal wall at which a hernia may later develop. Secondly, in itself it renders a faecal discharge somewhat more likely by placing a greater strain on the suture line, in that less bowel is available for inversion with the limited mobilization permitted by this operation, and because a change in direction of faecal movement is unavoidable at the point of suture (Figure IIIa). On the other hand, if the bowel is thoroughly mobilized and placed in an extraperitoneal position, tension is reduced to a minimum and a more direct line of faecal movement is permitted (Figure IIIb). For these reasons subcutaneous closure is less satisfactory than extraperitoneal closure followed by a complete repair of the abdominal wall.

Pauchet Closure.

The literature contains few references to the Pauchet closure subsequent to 1930, when it was enthusiastically advocated by Davis.⁽¹⁹⁾ Instead of using

an enterotome Pauchet actually cut the spur between two long clamps and then inserted a continuous suture along the cut edges. Mobilization and extraperitoneal closure were then performed at once. However, one cannot readily

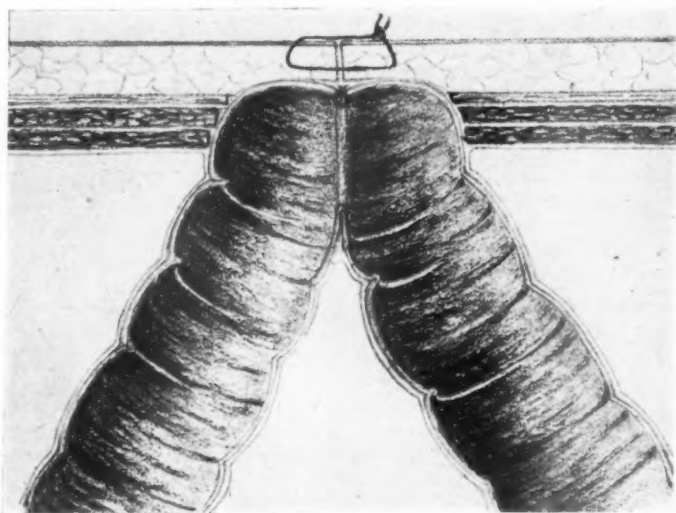


FIGURE IIIA. Subcutaneous closure.

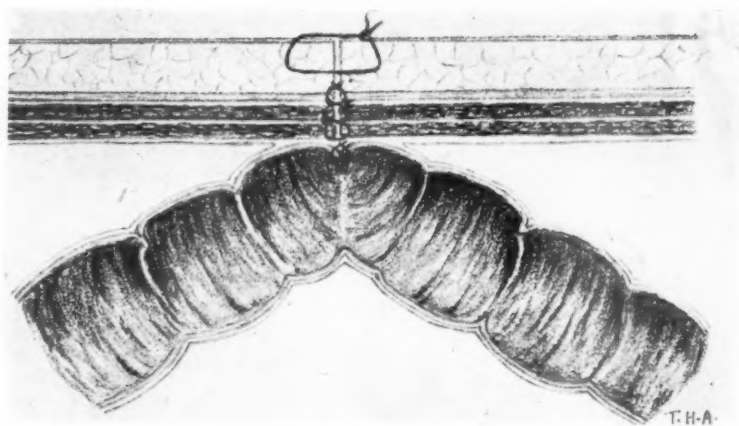


FIGURE IIIB. Extraperitoneal closure.

imagine how accurate suturing and haemostasis may be performed within the bowel lumen to a depth which is now known to be desirable. This technique has never become popular and is unlikely to displace the use of the enterotome.

Other Procedures.

Several other methods are sometimes employed but usually prove to be inadequate. They are: (a) the placing of an enterotome upon the spur, with

partial suturing of the skin at the same time; (b) the application of silver nitrate; (c) balloon pressure.

Although in some instances the discharge of faeces ceases some weeks after such procedures, it cannot be held that they are sufficiently effective to justify their use.

Extraperitoneal Closure.

Extraperitoneal closure is the operation of choice. It was first described in 1895 by J. Grieg Smith, although in an imperfect form, inasmuch as he did not advise preliminary crushing of the spur. For this reason the operation as performed by him must have resulted frequently in some narrowing of the colon at the site of closure and in all probability discharge of faeces occurred during the post-operative period in a fairly high proportion of cases.

The operation should not be performed earlier than a fortnight after the removal of the enterotome, by which time the mucosal edges at the site of crushing are partly or completely healed.

Pre-Operative Treatment.—The patient is given a non-residual diet for several days before operation. This step, although not essential, is nevertheless of value in that it assists in relieving the strain which is placed upon the bowel suture line during the early post-operative days when healing is occurring. Of greater importance, however, is the washing out of the colon proximal to the colostomy opening. This should be performed twice, namely, on the preceding evening and on the morning of operation.

Attention should also be given to the bowel between the colostomy and the anus. Adequate crushing of the spur is usually followed by the passage of some faeces into the rectum and normal bowel actions may occur. But in some cases the rectum becomes filled with inspissated faecal material mixed perhaps with remnants of a barium enema. "Wash-throughs" given from the colostomy will obviate this and should be repeated until the result is clear.

Nurses should be instructed to use the greatest gentleness in carrying out colostomy wash-outs and colon-rectum "wash-throughs"; the bowel has not infrequently been perforated by a stiff rectal tube roughly handled or pushed against resistance, often with a fatal result. A well lubricated soft tube should be used, and when the spur is poorly defined the surgeon himself should be present to supervise the procedure. In such cases it is unreasonable to expect a nurse to be able to differentiate the proximal and distal portions of the colon.

This risk of perforation of the colon is in itself a good reason why colostomy patients should not perform daily wash-outs by passing a rectal tube. Furthermore, when a colostomy behaves irregularly, the irritability of the bowel may only be increased by a "wash-out" routine and a state of catarrh with excessive mucus formation may result. The exclusion of fruit and vegetable roughage from the diet, and medical measures such as the use of kaolin and bismuth usually succeed in producing formed actions with a tolerable degree of regularity.

Anæsthesia.—Spinal anæsthesia is unsuitable, as the resulting stimulation of peristalsis may flood the wound with faeces. This not only constitutes a serious inconvenience, but also an appreciable danger if the peritoneal cavity is open at the time. Ether is the most suitable anæsthetic, with local infiltration a satisfactory alternative.

The Technique of Extraperitoneal Closure.

The bowel openings are cleansed with swabs dipped in an aqueous antiseptic solution, such as "Dettol", and tincture of iodine is applied to the surrounding skin. A gauze plug is placed temporarily in the proximal



FIGURE IVa. Incision for closure of an inguinal colostomy. A = incision, B = scar, C = skin to be excised.

colon be accidentally incised, the laceration is best repaired at once with a few interrupted sutures of fine catgut. The external oblique or anterior rectus sheath is then divided for a short distance above and below the colostomy opening and the bowel wall separated entirely from the aponeurosis—again with the assistance of a finger in the lumen if necessary.

colostomy stoma. The shape of the incision which is required around the colostomy openings depends upon whether a skin bridge lies between the stomata or not.

Figures IVa and IVb illustrate suitable incisions for the closure of (a) an inguinal colostomy with no skin bridge and (b) a transverse colostomy in which the stomata are completely separated by skin and subcutaneous tissue.

The subcutaneous tissue is divided until the aponeurosis of the external oblique or the rectus sheath is recognized. These structures may be identified more easily if the incision is first deepened through unscarred tissue at the upper and lower ends of the wound. Great caution is required. Not infrequently there exists some degree of ballooning into the subcutaneous tissues of the bowel adjacent to the colostomy opening, especially in relation to the proximal stoma. If this is so, the outer muscle layer of the bowel may be injured more easily during its separation from the subcutaneous fat. The likelihood of such an accident is minimized if the index finger of the left hand is placed in the lumen of the intestine while the dissection is being performed—an invaluable aid which should always be employed when difficulty arises in discerning the correct plane of separation (Figure V).

Admittedly a greater degree of wound contamination will result, but the manœuvre is justified in such cases by the added accuracy which is gained. Should the muscle layers of the

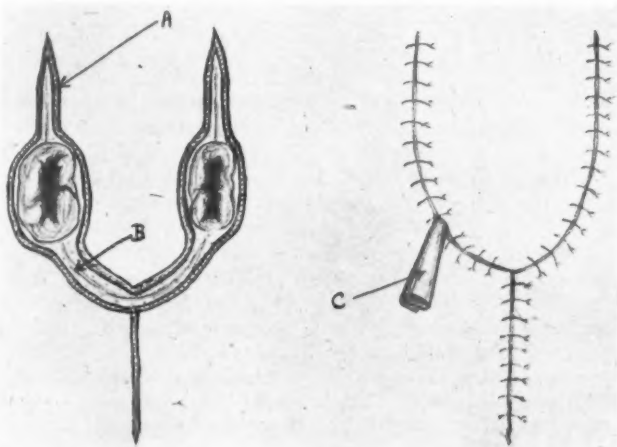


FIGURE IVb. Incision for the closure of a transverse colostomy with a skin bridge. A = incision, B = scar and skin to be excised, C = glove drain.

Separation from the deeper muscle layers is now required. During this step each cut must be made as close as possible to the bowel wall itself and with particular care, for the peritoneal cavity is often opened accidentally at this stage. Such an occurrence is of no importance providing that the rent is at once recognized and carefully repaired.

The bowel should be so thoroughly mobilized by division of all connexions between it and the deep muscle layers that it may be lifted freely from the wound and also replaced easily in an extraperitoneal situation. Free mobilization undoubtedly increases the chance of a successful closure.

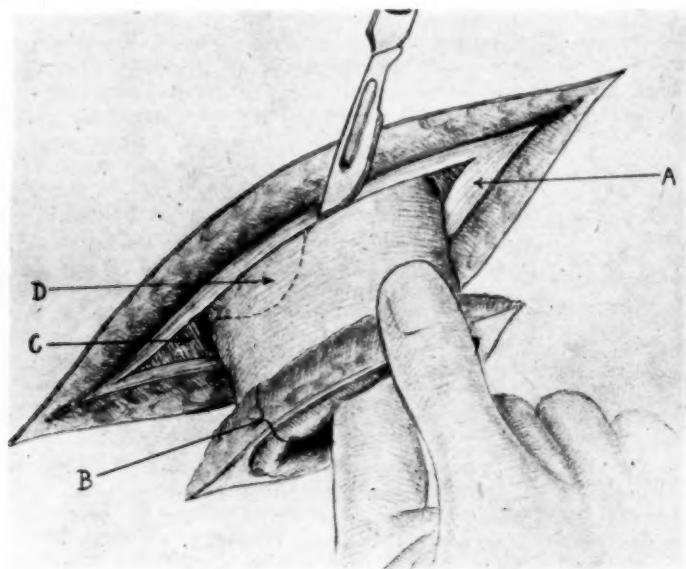


FIGURE V. The dissection of an inguinal colostomy. A = external oblique muscle; B = cuff consisting of skin-mucosal junction and fat, to be excised; C = internal oblique and transversus muscles; D = pouch of peritoneum drawn out by traction. It may be opened accidentally at this stage.

When this dissection has been completed the bowel itself must be prepared for suture:

1. The junction of skin and mucous membrane is often found to be in a condition illustrated in Figure VI. The mucous membrane is pointing and everted irregularly above the level of the narrow ring of skin which has been left as a result of the first incision. Many surgeons remove only this ring of skin, while others leave the whole "cuff" untouched, believing that a margin of skin enables the bowel sutures to hold more securely. But a regular inturning is impossible under such circumstances and, moreover, well-performed Connell suturing requires no such aid. A neater and safer suture line is likely to be produced if the whole of the irregularly pointing mucosa and skin is removed by cutting around the circumference of the stoma with scissors. Obviously an unnecessary sacrifice of colon wall must be avoided, but the spur should have been crushed sufficiently to allow this trimming to be done without a constriction resulting after the bowel suture line has been inserted.

2. Indurated *appendices epiploicae* or portions of subcutaneous fat which have been left adherent to the bowel wall should be removed. Lahey⁽⁷⁾ has

drawn attention to the great importance of this step in restoring the ordinary degree of intraperitoneal bowel flexibility, without which accurate inversion cannot be achieved. The actual suture of the stoma is best performed in two layers—firstly, an inverting “all-coats” Connell suture of chromicized catgut, and following this an additional row of interrupted sutures passing through colon muscle only. Silk and thread are unsuitable in this procedure, for they may be responsible for a long-persisting sinus which will not close until the sutures are discharged or removed. The wound is thoroughly irrigated with a solution of “Monacrin”, 1 in 1,000, and sulphamide-penicillin powder is insufflated.

Drainage.—An incision into scarred tissue usually causes a good deal of diffuse capillary oozing which cannot be fully controlled by artery forceps and ligatures; a probable explanation is that the cut ends of small blood vessels are held open by the fibrous tissue matrix in which they run. A wound produced at the closure of a colostomy stoma is an example of this, and a post-operative hematoma is not infrequently seen in spite of the greatest care. A drainage tube or small piece of corrugated rubber should therefore be placed through the sutured muscle layers to the extraperitoneal plane and left *in situ* for forty-eight hours. In this way an ideal pabulum for infection may be prevented and a factor which may contribute to the breakdown of the bowel suture line may be avoided.

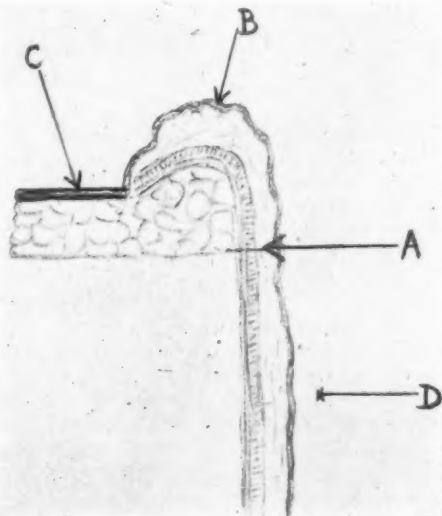


FIGURE VI. The skin-mucosal junction. A = line of trimming incision, B = pointing mucosa, C = skin, D = lumen of colon.

Delayed Closure of the Incision.

Pemberton and Black¹⁰ of the Mayo Clinic, have recently advocated the delayed closure of wounds made at the closure of colonic stomata. They recommend that after the bowel has been mobilized and oversewn and the muscle layers approximated with catgut, an iodoform pack should be placed in the wound and the skin left with its sutures inserted but untied. At the end of forty-eight hours the pack is removed and the sutures are tied. These authors quote a series of 94 closures, one half of which were made by primary suture and the remainder by this delayed method. The results shown in Table III were obtained.

It would appear from these figures that the procedure possibly does provide an advantage. Delayed suture is, of course, no new method and was used extensively by French surgeons in 1918. The term implies that the wound edges can be brought together at once without any further incisions being required, in distinction to secondary suture, in which new epidermis requires excision. Why temporary packing should lessen the risk of infection spreading when the wound is closed is not clear. Collier and Valk¹¹ have shown that the packing alone provides no bactericidal effect; but it certainly prevents the

formation of an enclosed hæmatoma and leads to coagulation in the cut ends of lymphatics, so that bacteria are less rapidly and less widely absorbed.

TABLE III.

Result.	Primary Suture. 47 Cases.	Delayed Suture. 47 Cases.
Successful	30	40
Fæcal discharge	17	7

Delayed suturing in all cases is probably an unnecessary precaution if sulphonamides are given in the post-operative period and if drainage is provided. On the other hand, it is wise if an excessive amount of fæcal contamination has been unavoidable, as, for example, when colonic peristalsis has unfortunately flooded the wound with bowel contents.

Post-Operative Treatment.

The avoidance of paraffin in the immediate pre-operative or post-operative period is of great importance, for a small amount of this substance may, by reason of its physical nature, make its way through the bowel suture line and so initiate a fæcal discharge. Furthermore, no other purgatives should be given. The patient will often state that he is conscious of flatus making its way through the repaired bowel into the rectum. Should flatus escape from the wound, however, this invariably means that the closure will be a failure and fæces will follow in a day or two. In successful cases the first normal bowel action is best brought about on the fourth or fifth day by means of a small glycerine enema. I believe that the routine post-operative administration of sulphonamides and penicillin to these patients is an assistance in lessening the cellulitis which usually occurs in some degree around the wound. The drainage tube is removed at the end of forty-eight hours; or, if delayed closure has been employed, the pack is removed and the sutures are tied.

It will be observed from Table I that in 55 "failed" cases healing finally occurred in 33 without any other operative interference being required. One may anticipate this satisfactory termination especially when the spur is known to have been adequately divided and when no distal obstruction exists. Hence, if a fæcal discharge occurs, treatment should be conservative for many weeks.

SUMMARY AND CONCLUSIONS.

1. Serious or even fatal complications may be associated with spur crushing. These are avoidable by correct technique.
2. Intraperitoneal suture involves an unjustifiable risk.
3. Extraperitoneal closure, if performed with care, is a safe procedure which can produce a successful result in a high proportion of cases.
4. A painstaking dissection is required and complete mobilization of the bowel should be secured.
5. Success also depends upon a variety of other factors; adequate spur crushing, the absence of distal obstruction, the preparation of the bowel edge for suture, an accurately inverting suture line, and the prevention of closed infection adjacent to the sutured bowel.

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Surgical Technique.

THE ESTLANDER-ABBE OPERATION.¹

By BALCOMBE QUICK,
Melbourne.

In 1877 Estlander described a plastic procedure in which a triangular portion of one lip, usually the upper, immediately adjacent to and including the angle of the mouth, is swung upon a narrow medial pedicle into some defect in the lateral portion of the neighbouring lip (Figure I). The inclusion in the pedicle of the coronary artery, which lies 0.5 to 1.0 centimetre from the muco-cutaneous junction of the vermillion border, ensures the vitality of the flap after its rotation of upwards of 180° into the new site.

The method found a particular field of usefulness in remedying those considerable deficiencies in the lower lip created by the wide excision of malignant growths there.

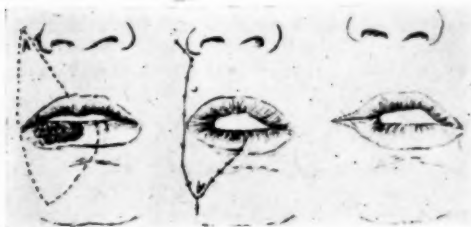


FIGURE I.



FIGURE II.



FIGURE III.

Apparently unaware of Estlander's description, Abbe published details in 1898 of a secondary operation for a case of hare-lip. In this, after incision or excision of the original suture line, a pedicled flap from the lower lip was swung across the mouth to amplify a tight, flat, upper lip, the appearance of which left much to be desired.

The underlying principle of the two operations, the inclusion in a narrow pedicle of the coronary artery, is identical, the only variant being that the pedicle in Abbe's method is more or less median in position, crossing the mouth here as shown in Figure II, which is taken from his original article.

¹ Accepted for publication on October 19, 1945.

By whichever name the method is designated, it is sufficiently well known to those who are interested in plastic surgery, for it is a perfect example of one of the basic principles of this art—the remedying of a deficiency by the introduction of a like and perfectly matching tissue derived from a site



FIGURE IVa.



FIGURE IVb.



FIGURE IVc.

whence it can well be spared. It would appear, however, that many general surgeons are less well aware of the possible applications of the method described by Estlander and Abbe, and for that reason attention may perhaps be drawn to its utility.

Any considerable disparity in the horizontal width of the lips leads to an unsightly deformity in which the normal lip, whether upper or lower, appears



FIGURE IVd.



FIGURE IVe.

hopelessly redundant in comparison with its narrowed neighbour. This is especially obvious and objectionable in the case of a child or young adult in whom the result of an operation for hare-lip, either single or double, has been indifferent in this respect.

Disfigurement is greatest in those cases of double hare-lip in which the intermaxillary bone has been removed or the prolabium excluded from the reconstruction. Here the flattened upper lip, often so narrow and tight as to make the wearing of an appropriate denture difficult or impossible, contrasts most painfully in profile with the pouting lower one (Figure III).



FIGURE VA.



FIGURE VB.



FIGURE VC.

In such the Abbe operation has been employed by the writer with considerable satisfaction on a number of occasions, and the present report is prompted in part by a desire to remind the general surgeon of the applications of this operation, and in part because one of the cases chosen for illustration furnishes an example of an interesting allied congenital defect.



FIGURE VD.

THE OPERATION.

Whilst it is not necessary to dwell at length upon the details of operation, there are, nevertheless, certain points to which attention may be drawn.

1. The position of the coronary artery must be determined with care, for upon its integrity the life of the flap depends. It is always possible to feel the pulsations of the vessel where it runs, almost directly under the mucosa, one



FIGURE VE.

centimetre or rather less from the vermilion border. Provided the artery is certainly intact, the remainder of the pedicle can be of very modest dimensions. In practice there is never any difficulty in swinging the flap across the mouth without tension or undue angulation resulting.

2. The horizontal width of the triangular flap will be decided by the needs of the individual case, attention being paid to the fact that the amount

of gain to the recipient lip is the measure of loss to the donor one. Neglect of this obvious consideration may lead to over-restoration of width in the recipient. This in turn may result in an undesirable appearance of lengthening of the upper lip (Figure IVd). The statement has been made that the width



FIGURE VIA.

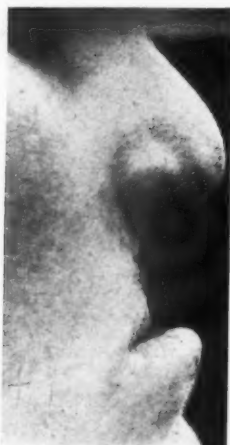


FIGURE VIB.

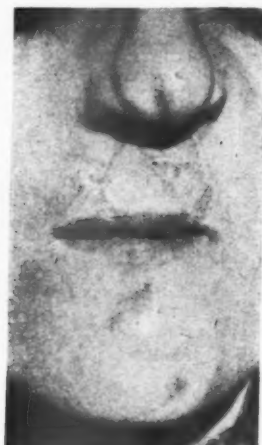


FIGURE VIC.

of the flap should be only half that of the estimated tissue loss—that is, an equal distribution of tissue loss between the two lips. This advice is probably sound in relation to the repair of operative deficiencies in the lower lip following the removal of a large epithelioma. But in those deformities of the upper lip resulting from the repair of a congenital defect it is exceedingly



FIGURE VID.



FIGURE VIE.

difficult to compute deficiency by caliper measurement. In such cases it is notable, too, that the lower lip often appears to be unduly full and protuberant. For these reasons it seems that the appropriate width of flap can be judged only after some experience in the matter and after consideration of both donor and recipient areas.

3. Both the vertical length and the shape of the triangular flap merit attention. A long and tapering flap creates a defect at the donor site which lends itself well to closure without puckering. But the viability of the sharply

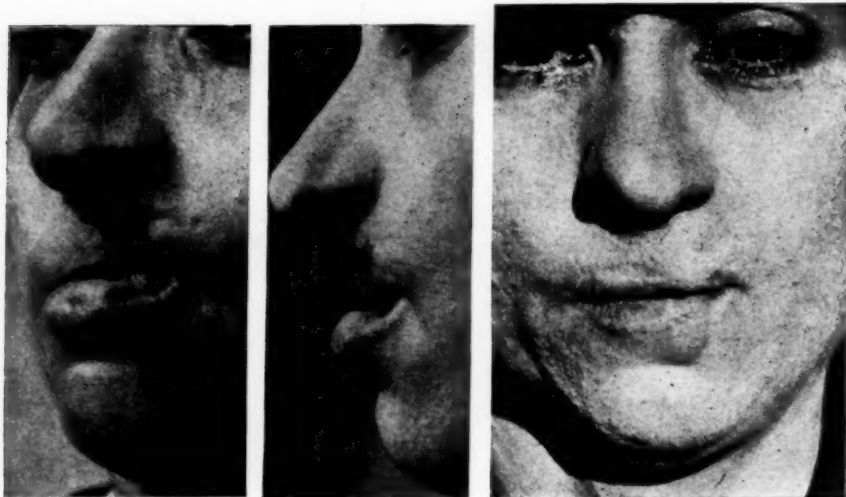


FIGURE VIIA.

FIGURE VIIB.

FIGURE VIIC.

angled extremity is questionable and the result of suturing the long narrow apex into the recipient defect may well be an anæmic necrosis with delayed healing and scar formation. For this reason it is often wise to excise the acutely angled tip before suturing.



FIGURE VIID.

FIGURE VIIE.

FIGURE VIIF.

4. As in all operations for hare-lip, the accurate alignment of mucocutaneous junctions is important if small secondary Z-type rectifications are to be avoided. This obligation applies not only to the recipient lip, but to

the donor site after the division of the pedicle. Commonly enough, later small adjustments are necessary to secure uniformity in width of the vermillion border. Any remains of vermillion border that may have been included in the lip at the original operation in infancy should be carefully excised. Neglect to do so may mar an otherwise very satisfactory cosmetic result (Figure VE).

5. Marginal vascularization of the rotated triangular flap is rapid owing to the very free blood supply of the lips, and division of the pedicle is safe after twelve to fourteen days' interval. At this same time the vermillion border of the lower lip is accurately restored.

6. Feeding during this time presents no real difficulties. Egg flips *et cetera* are given by tube for the first few days and later a small spoon may be passed at the corner of the mouth.

7. The application of a special head-piece and harness, as has been recommended to prevent involuntary opening of the mouth after operation, is unnecessary. If, however, the operation has been carried out under general anaesthesia, the passage of a suture through the tongue is a wise precaution against possible respiratory difficulty after the patient leaves the theatre (Figure VIe).



FIGURE VIII.

8. Although the operation can be carried out under local anaesthesia, which has certain obvious advantages, it is rather more difficult to assess the amount of tissue to be included in the rotation flap after infiltration.

No anxiety need be felt as to the ultimate function and mobility of either lip. Matthews⁽¹⁾ states that "the resultant upset to the muscular control of the mouth is rather more severe than after the reverse procedure to repair the lower lip". Such may well be the case when the demands created by wide removals in malignant conditions are to be met, but within the limits set by the comparatively reasonable requirements in the type of case under consideration here no interference with control has been at all evident. On the contrary, it has happened that a pre-existing salivary leakage has been remedied. With improvement in appearance, too, there have been instances of a gratifying loss of self-consciousness, evident both by a change in facial expression and by a commencing desire to mingle in society (Figure VII).

CONGENITAL FISTULÆ OF THE LOWER LIP.

The interest attaching to the rare congenital deformity of fistula of the lower lip lies in the difficulty in finding a convincing embryological explanation for its occurrence. In those few instances in which it is not associated with hare-lip or cleft palate, there is almost always a family history of such. The great majority of instances occur in the female, as in the case illustrated (Figure VIIf). In this young woman the constant presence of a glistening drop of clear mucus at the orifice of each fistula constituted an additional cause of complaint and mortification. Keith, indeed, has endeavoured to explain the occurrence as a reversion to the mucous glands of the lip of the shark. Microscopic examination of the tissue removed in excision of these fistulous tracts, which were about one centimetre deep, failed to reveal any mucin-secreting glandular structures. An alternative explanation which has had some acceptance is that the condition represents a persistence of the groove, evident in late foetal life, between the smooth or glabrous outer and

the papillary inner zones of the lip. Supporting this hypothesis is the description, applied to several reported cases,⁽¹⁾ of the slit-like nature of the orifices, the slit running in the coronal plane. Such a description is not applicable to the case illustrated (Figure VIII). The orifices were not slit-like, but circular, with raised margins. The relationship to the mucocutaneous junction, moreover, lacked the symmetry that might be expected if both represented the persistence of a groove or furrow. So it may be said that study of this case contributed nothing to an understanding of the aetiology of this interesting condition, although the removal of the pits, by simple dissection, afforded the patient the greatest satisfaction.

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Case Reports.

CONGENITAL BIPARTITE CARPAL NAVICULAR.¹

By THOMAS F. ROSE,

Major, Australian Army Medical Corps.

A BIPARTITE carpal navicular is one in which the navicular consists of two more or less equal portions separated by a narrow joint cavity. It is a congenital condition, usually, though not always, bilateral, which in itself gives rise to no disability. A knowledge of its presence in a patient who has a wrist injury is important, however, because it is easily confused with an ununited fracture of the navicular, especially if the wrist is not investigated radiologically until some time after the injury is sustained.⁽²⁾ In civilian life the differentiation between an ununited fracture of the navicular and a bipartite navicular is of medico-legal importance, especially if compensation is involved. It is also of importance in the army from the point of view of the correct classification of the soldier and the likelihood of later pension claims.

Clinical Report.

A thirty-seven-year-old soldier, who had never had any symptoms referable to his wrists before, slipped whilst lifting a heavy object. The sudden dropping of the weight forced his right wrist into hyperextension, causing severe pain on the anterior aspect of the hand and forearm.

He did not report for treatment until one month later, when his wrist was still painful and weak. An X-ray examination of the wrist was made and was said to reveal an ununited fracture of the navicular.

He was referred to hospital for treatment of this condition, but did not appear until a month later. Examination then disclosed a muscular right-handed man. The only abnormalities found in the right wrist were some deep tenderness over its anterior aspect, weakness of the hand grip and ten degrees of limitation of active extension as compared with the left wrist. There was no tenderness elicited on pressure of the navicular in the anatomical snuff-box. An X-ray examination of the right wrist was again made (Figure I) and the condition was seen to be similar to that seen originally. Owing to the unusual appearance of the navicular, the left wrist was examined by X rays and similar findings were found in the left navicular (Figure II). Each navicular was divided into two portions through the waist by a curved, sharply defined, narrow space, which ran obliquely from near the outer end of the articular surface of the radius to the head of the capitate. Its edges were regular, smooth and thin. The bone texture of each fragment was of equal and normal density, and there were no areas suggestive of necrosis or cystic formation.

The lesion of the right wrist was then diagnosed as a tear of the volar radio-carpal ligament due to hyperextension of the wrist joint, in a patient who had coincidental bipartite naviculars.

The wrist was immobilized in a plaster cast for one month and the patient then had normal painless wrist movement. He was examined three months later and was performing heavy work without disability. A further X-ray examination of both wrists revealed exactly the same appearances as previously.

Discussion.

Etiology.—The navicular is a compound bone formed of two main elements, a radial and ulnar, and two accessory bones, the *os radiale externum* incorporated in the tubercle, and the *os centrale*, which may, however, fuse with the capitate or remain as a separate ossicle on the dorsum of the carpus.⁽³⁾ Normally these elements fuse before birth, but they may remain separate, giving rise to a variety of abnormalities. The case presented here represents the true bipartite navicular in which the radial and ulnar elements remain separate.⁽⁴⁾

Most commonly bilateral, though unilateral cases have been reported,⁽⁵⁾ this condition is not rare, occurring about once in a thousand persons.⁽⁶⁾ It may be familial and an instance of it occurring in ten relatives has been recorded.^(6a)

Anatomy.—A true bipartite navicular is divided across the waist into more or less equal portions.⁽³⁾ There is a joint space between the fragments and its cavity

¹ Accepted for publication on January 3, 1946.

communicates with the carpal joint system, but is separated from the radio-carpal joint by a ligament uniting the proximal edges.⁽¹⁾ The joint surfaces are covered with a cartilaginous coating⁽²⁾ overlying the thin layer of *substantia corticalis* of the fragments.⁽³⁾ The bone texture of both fragments is normal, as each has its own blood supply. The line of division runs obliquely from near the outer end of the articular surface of the radius to about the middle of the concave surface of the head of the capitate.



FIGURE I.

rests on the radiological findings. These shows that the bone texture is normal and of equal density in each fragment of a bipartite navicular. The dense picture of aseptic necrosis that may occur in the proximal fragment of an ununited fracture is not seen. The apposing edges of the fragments are smooth and thin, and there is no evidence of osteoporosis or thickening of the edges due to osteosclerosis. Should any change be seen in the texture of the proximal fragment suggesting avascular necrosis, or if there is any irregularity or increased density in the line of demarcation, then the separation is due to fracture, even if the condition is bilateral and the patient cannot remember an injury.⁽⁵⁾

Bunnell⁽²⁾ points out, too, that in a fairly recent fracture of the navicular serial X-ray photographs will show progressive changes in the bone as it proceeds to either union or non-union. Lack of such change indicates bipartite navicular rather than fracture.

A bipartite navicular is subject to the same traumata as a normal navicular, and Childress⁽⁴⁾ has reported a case in which there was a fracture of the distal fragment in a bipartite navicular, so confusing the radiological appearance. Brailsford⁽⁵⁾ states that X-ray evidence of the presence of arthritis of the other carpal bones is diagnostic of ununited navicular fracture, but Boyd⁽¹⁾ says that this may occur in conjunction with a bipartite navicular also.

Ununited fracture of the right navicular was accordingly excluded in this patient for the following reasons. The trauma was a hyperextension injury of the wrist which may cause a tearing of the volar radio-carpal ligament, but not a fracture through the waist of the navicular. The radiographs of both wrists were typical of bipartite

Diagnosis.—This condition must be diagnosed from an ununited fracture of the navicular. It is usually stated that, if there has been no previous history of injury, if no disability is present, and if the condition is bilateral, then the case is one of bipartite navicular. However, Watson-Jones⁽⁴⁾ points out that these criteria are unreliable, because injuries, so slight that they may have been forgotten, may cause a crack fracture of one or even both naviculars. Little disability may be caused and few abnormal physical findings be present, yet an X-ray examination made some time after injury will show an ununited fracture of the navicular.

Consequently, though the negative history of injury and the bilateral nature of the lesion may make one suspect a bipartite navicular, the final decision



FIGURE II.

navicular and serial pictures showed no changes in the five months after injury. The ligamentous damage was healed by immobilization for only one month. A fractured navicular, if symptomatically cured in that short time, would show evidence of commencing union.

Summary.

The case history of a patient, originally diagnosed as suffering from an ununited fracture of the right navicular following injury to the wrist, is presented. It is shown that the true diagnosis was a tear of the volar radio-carpal ligament due to a hyperextensive force. The patient had a coincidental bilateral bipartite navicular.

The aetiology, anatomy and radiological appearances of this condition are described briefly. The importance of diagnosing it from ununited fracture of the navicular is stressed and the points of differentiation are discussed.

Acknowledgement.

I wish to thank the Director-General of Medical Services, Australian Military Forces, Major-General S. R. Burstn, for permission to publish this paper.

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Surgery in Other Countries.

[In this column will be published short résumés of articles likely to be of practical value from Journals published in other countries and not readily accessible to surgeons in Australia and New Zealand.]

HERNIATED NUCLEUS PULPOSUS IN AN INTRADURAL POSITION.

O. Hultén: "Intradural gelegener Diskusprolaps", *Acta chirurgica Scandinavica*, Volume xcii, 1945.

THAT a herniated *nucleus pulposus* can cause an extradural compressing tumour is common knowledge, but that a *nucleus pulposus* should make its way through the anterior wall of the spinal theca and lie intradurally would be called very improbable. The case reported shows that this can, however, happen.

The patient was a man aged thirty-nine years, who had suffered ten years previously from acute sciatica of undiagnosed origin. A year later the symptoms reappeared, but eased following treatment by baths *et cetera*. Thereafter he was well until 1942, when he did his military service. In February, 1943, he complained of stabbing pains in the region of the right hip and on the outer surface of the right thigh. These were swiftly followed by paræsthesia in the whole of the right lower limb, with intermittent numbness in the toes of the right foot. During May, 1943, weakness in the right foot developed and some pain and loss of power also became apparent in the left leg. Micturition became impaired, and when the patient was admitted to hospital on May 21 he had complete retention of urine. Clinical examination on that day showed complete paralysis of the right foot and a general paresis of the right lower limb, with evident but lesser paresis in the left limb also. The circumference of the right lower limb, both in the thigh and the leg, was three to four centimetres less than that of the left. Sensation was abolished on the right side in the segmental areas lumbar V to sacral V, and on the left side in segments sacral II to sacral V. The cerebro-spinal fluid was normal in all respects, including its pressure. X-ray examination with contrast material in the spinal canal indicated a tumour at the level of the fourth lumbar vertebra. At operation, after laminectomy a tumour the size of a cherry, and of the consistence of cartilage, was seen glistening through the posterior wall of the theca. When the dura was opened this tumour was found to be lying among the trunks of the *cauda equina* and was attached by a pedicle to the anterior wall of the canal. When the tumour was pulled on it was seen that the "pedicle" lay in a canal 2.0 by 4.0 millimetres in area and 42.0 millimetres long, situated in the intervertebral disk. The whole tumour, including its pedicle, was withdrawn and removed easily, and on histological examination was proved to consist of the *nucleus pulposus*.

Such an occurrence is perhaps to be explained on the theory of an adhesion between the dura and the intervertebral disk, but the original reason for the formation of such an adhesion is no nearer to being explained.

ARTHUR E. BROWN.

DIVERTICULA OF THE URINARY BLADDER.

L. M. Rognon: "Le traitement des diverticules vésicaux. Résection cervicale pure, ou diverticulectomie", *Journal de chirurgie*, Volume lxi, 1945.

Ever since diverticula have been known to exist in the bladder, surgeons have devised various methods of dealing with them. Surgical resection, owing to its great dangers, fell early into disfavour; but since Marion evolved his method of resecting diverticula from within the bladder itself, the surgical line of attack has made headway.

On the other hand, the development of the technique of perurethral resection of bladder-neck obstructions has brought into being new ideas on the association of such obstructions with the formation of diverticula. Marion himself pointed out that ablation of the diverticulum was not sufficient to bring about a functional cure while any bladder-neck obstruction still existed. The point was brought out at a congress in London in 1933, and since then the pendulum has swung so far that many now claim that only the obstruction need be attacked and that the diverticulum may be regarded as a harmless secondary phenomenon.

In this paper 34 cases are reviewed. They have all been met with between January, 1939, and January, 1944, and all the patients were males. Rognon groups them into:

(a) those treated by diverticulectomy with or without bladder-neck surgery; (b) those treated by endoscopic resection without interference with the diverticula; (c) those treated by surgical resection of the obstruction, the diverticula being left alone.

In the first group, reflecting Rognon's own predilections, were 25 patients. Marion's technique of diverticulectomy was employed, the diverticulum being dissected out from within the bladder and from above downwards, in the manner in which a hernial sac is removed. The resultant space is packed with gauze which is brought out through the bladder. At a later stage whatever obstruction there was at the bladder neck was surgically dealt with. The results in this group, apart from one post-operative death, were entirely satisfactory. In a late follow-up review of ten of the patients, eight claimed to be entirely free from all symptoms; one had no evident symptoms, but a persistent pyuria and some residual urine. The tenth case was only moderately successful as a late result.

In the groups of patients treated without removal of the diverticulum there were five whose obstruction was resected per endoscope; and four, including two whose bladders were affected by generalized diverticulosis, whose obstruction was surgically corrected. Of these nine patients, one has achieved a perfect functional and anatomical result, the diverticulum having disappeared. All the others continue to exhibit dysuria and pyuria and have a significant amount of residual urine, although six of them found their symptoms lessened by the operation. The results even from the point of view of function were not equal to those obtained by diverticulectomy; but the improvement that these aged and frail patients did succeed in getting was important to them. In view of the disappearance of the diverticulum in the first case of this group, it would seem wise if, as Dosset suggested should be done, further close study were made of the method of emptying each diverticulum.

The general results in this series differ widely from those claimed by the partisans of simple cervical resection. They hold that diverticulectomy is so grave and dangerous an operation that it should be avoided in most cases. Only one of Rognon's 25 patients died from the operation, and with the more modern technique the danger should be nearly eliminated. They also state that relief of the cervical obstruction afforded to these patients is sufficient to produce a complete cure in a functional sense. This series indicates that cervical resection by itself is not nearly so effective as is diverticulectomy combined with resection. When any diverticulum worthy of the name exists, in any patient in whom operation would be a reasonable surgical risk, both procedures should be employed in conjunction.

ARTHUR E. BROWN.

END-TO-END SUTURE OF THE DUODENAL STUMP TO THE STOMACH IN GASTRECTOMY.

F. D'Allaines and Dubost: "Opération de Péan: Indications et technique", *Journal de chirurgie*, Volume lxi, 1945.

THIS article is a plea for a return to the end-to-end union of stomach to duodenum after gastrectomy. The authors refer to it as Péan's operation, though to non-French readers it is more familiar as the Billroth I method. Since the work of Pauchet and of investigators in other countries the procedure has little by little come back into good repute. D'Allaines and Dubost published the results of 36 such operations before the *Académie de chirurgie* in November, 1944, and since then have had experience with 33 further cases. They are fully satisfied that the operation will give excellent results, and with no greater risk than is associated with other more popular forms of gastro-intestinal anastomosis.

Among contraindications they will not accept as valid the argument that in order for the operation to be successfully performed the extent of the stomach resection must be unduly restricted. Their usual resection comprises from two-thirds to four-fifths of the stomach, and they have on three occasions anastomosed the duodenal stump to the stump of the œsophagus direct after total gastrectomy. Post-operative vomiting used to be dreaded, but with the use of continuous suction drainage of the stomach, which should be used whatever form of gastro-duodenal anastomosis is adopted, this danger no longer exists. Even in one series in which this precaution was not taken, there was no more post-operative vomiting than is seen after any other method. A third alleged danger is that of secondary stenosis; but the authors just state it has not occurred in their experience. The most dreaded of all complications following end-to-end suture used to be duodenal fistula. With careful modern technique this need not be feared.

The only valid general contraindications to the procedure are those which operate equally against gastrectomy of any sort—the general condition of the patient. There are on the other hand certain local considerations. The duodenum must not be the seat of deep penetrating ulcers of the posterior wall. Such cases require the sacrifice of too much of the duodenum for the end-to-end suture to be practical. Small ulcers on the

anterior wall have no such significance. The duodenum also should be mobile or capable of being thoroughly mobilized. This is swiftly and easily done along the outer border of the second part of the duodenum. It is neither necessary nor wise to include in the stripping so much of the first part as will endanger the blood supply. The duodenal wall should be thick and vascular for the suturing of it to be done with safety and success. Occasionally a duodenum which, at the moment of resection appears to be too soft and tenuous for safe suturing, is found later in the operation to be quite thick and firm. But care in this respect must be exercised.

The operative technique is the important factor in success. Post-operative and pre-operative care is the same for this as any other type of gastrectomy. The first step is the freeing of the upper part of the duodenum and the freeing of it from the pancreas. The pyloric and gastro-epiploic arteries having been secured, the duodenum is cut across. It is at this stage that the decision must be made whether to proceed with the end-to-end suture or to close and turn in the duodenal stump and conclude with a gastro-jejunostomy of one or other form. Free mobilization of the duodenum follows the decision, and the anastomosis of the cut end to that of the stomach follows according to the usual principles of technique in such operations.

ARTHUR E. BROWN.

THE FREQUENCY OF GASTRIC AND DUODENAL ULCERS.

Gustav Petrén: "Zur Frequenz des Magen- und Duodenalgeschwürs in Schweden während der Kriegsjahre", *Acta chirurgica Scandinavica*, Volume xcii, 1945, Number 2.

THIS review of the increased frequency of gastric and duodenal ulceration during the war, in a neutral country, is based statistically very largely on the occurrence of actual perforation. The number of cases of perforated ulcer in which operation was performed supplies almost the only unassailable indication of the general incidence of ulceration which would not be based largely on guesswork. And in a limited community such as Sweden, this index can be properly collated and studied. All patients operated upon, in private as well as in public hospitals, are included in the figures, except for such occasional cases as must occur in places like the northern parts of Sweden, where transport facilities are so rudimentary that the patient never reaches a doctor, or such other few cases in which the patients arrive at hospital in a condition so nearly moribund that operation is regarded as useless.

Complete figures have been collected for every year since 1930 until 1943. Throughout these years there has been a steady increase in the total number of perforations; and this steady increase is also a proportional increase relative to the total population. Incidentally, too, there is shown, though this is not part of the object of the paper, an equally steady decrease in the percentage mortality. Although the increased incidence of perforated ulcer has been continuous through all the years, it has been shown to have been comparatively gradual in the years from 1930 to 1941, but to show a sudden and sharp rise in the years 1942 and 1943.

Petrén depicts the position graphically by four tables, which may be summarized as in the accompanying table.

Year Period.	Number of Operations.	Number of Deaths.	Percentage Mortality.	Average Number of Operations per Annum.	Operations per 100,000 of Population per Annum.	Percentage Rate of Increase.
1930-31 ..	907	190	20.9	439	7.38	—
1932-33 ..	891	181	20.3	446	7.20	—
1934-35 ..	1,019	190	18.7	509	8.17	12.1
1936-37 ..	1,085	201	18.5	543	8.66	6.0
1938-39 ..	1,151	213	18.5	576	9.12	5.3
1940-41 ..	1,259	222	17.6	630	9.88	7.2
1942-43 ..	1,594	215	13.5	797	12.33	24.6

Looking for possible fallacies in these figures, Petrén asks how truly does an increased incidence in perforation reflect an increased incidence of actual ulcer formation. Ulcers perforate more often, for instance, in men than they do in women; and duodenal ulcers are more subject to perforation than are gastric ulcers. If, then, there should occur an increase in the number of duodenal ulcers relative to that of gastric ulcers, or an increase in male ulcer sufferers relative to women, the proportion of ulcers that perforate may be expected to be greater than it had been, and the figures may not reflect truly the increased incidence of ulceration. The proportionate increase

of duodenal ulcers and male patients has obviously actually occurred in the past two decades. Again, many statistical reports have shown that some 50% to 60% of perforating ulcers have caused symptoms for more than a year before they perforated. In 40% to 50% the symptoms have lasted less than a year, while in some 10% to 15% the perforation is the first indication that an ulcer has been present. If, therefore, the Swedish figures seem to show that a great increase in perforations occurred in the year 1942, this may mean either that a greater number of old-standing ulcers have gone on to perforation or that a greater number of new ulcers are forming and perforating earlier.

If due allowance for these factors is made it remains to be said that a relatively great increase in perforations in a community during a given period could reasonably be held to indicate an increase in ulcer incidence. It is in fact so probable as to be reasonably certain that at the back of an increase in the number of perforations as great as 35% there must be a decided actual increase in ulceration. Petré is inclined to attribute this increase, even in neutral Sweden, as in other less fortunate countries, to malnutrition and to the mental and psychical stresses of the war years.

ARTHUR E. BROWN.

ARTICULAR DENERVATION AS A TREATMENT FOR OLD-STANDING CONGENITAL DISLOCATIONS OF THE HIP.

L. Tavernier: "*L'énervation articulaire dans le traitement des luxations congénitales de la hanche chez l'adulte*", *Lyons Chirurgical*, January-February, 1946.

THE motive which brings adult patients suffering from congenital luxation of the hip to the doctor is nearly always pain. They have managed to accommodate themselves fairly well to their limp; but there comes a time when walking causes pain and this pain becomes worse, limiting movement, increasing deformity and rendering them nearly helpless.

In view of this fact, treatment of the pain becomes a primary indication for therapy. Nerve section was commenced for this reason in 1938, and the results have encouraged its continuance. Where conditions seem to require it, as in younger people, osteoplastic procedures have been undertaken; but more and more the main reliance is being placed on denervation. Of fifteen patients on whom bone operations were performed, five failed to secure relief, while among nineteen subjected to nerve section (five of them having both hips treated, a total of twenty-four separate operations) there were only two failures.

The procedure adopted is section of the articular fibres of the obturator nerve, combined in later operations with section of the nerve to the *quadratus femoris* to complete the "denervation" of the hip joint. Among the nineteen patients in whom this complete procedure was carried out, both anterior and posterior articular fibres being cut, eight results were excellent and two were medium; two patients failed to secure relief. The seven first patients in the series were subjected only to the cutting of the obturator fibres, the nerve to the *quadratus* being left, and of these seven operations one could be classed as producing an excellent result, and in the other cases the result was only reasonably good. Those results were classed as excellent in which there was complete relief of the pain and lessening of the limp, and above all when the power of walking was altogether transformed. Results were called reasonably good when the pain was lessened, being either reduced to a slight pain or occurring only after a long walk, or persisting in a limited area only.

The two cases classed as failures were interesting in their results. In one case the pain was abolished for a period of a few weeks, in the other for seven months, but in both it then recurred. The shorter period of relief might have been explained as a result of the enforced period of bed rest, but it is difficult to see how relief lasting for as long as seven months could be due to such a temporary cause. On the other hand, it is a curious fact that in the case of some cured patients the relief was not immediate, but the pain disappeared gradually, in one instance taking a month to vanish. These two opposed phenomena are difficult to reconcile with current ideas on regional nerve section.

Denervation is the operation of choice for all patients over thirty years of age, in whom the main complaint is of pain, the limp being regarded as secondary, and who were able to walk well before the onset of the pain. It is a simple procedure, without danger to the patient, and it does produce good results. Bone operations are reserved for those younger people in whom the limp is the major factor, especially those with high iliac dislocations. Subcotyloid dislocations usually have a stability sufficient to carry the patients over until the condition becomes painful in later life. A secondary denervation of the hip is indicated in any case in which a bone operation has failed to give ease from the pain.

ARTHUR E. BROWN.

Reviews.

Further Studies in Encephalography. By E. GRAEME ROBERTSON, M.D. (Melbourne), F.R.C.P., F.R.A.C.P.; 1946. Melbourne: Macmillan and Company, Limited. 9 $\frac{3}{4}$ " \times 5 $\frac{1}{4}$ ", pp. 113, with 53 figures. Price: 45s.

MANY of the modern developments in neurology and neurosurgery can be attributed to the use of radiographic procedures in which contrast media are employed. The increasing accuracy in localization has brought more pathological conditions within the scope of surgical treatment. In his second monograph on encephalography Dr. Robertson pursues his investigation on the principles involved in the introduction of gases into the cerebro-spinal fluid pathways and elaborates more practical applications of this method.

The first portion of the monograph is concerned with an investigation of the factors influencing ventricular filling. A theory is produced which suggests that there are two separate mechanisms which control the entry of gas into the ventricles. That there is a downward displacement of cerebro-spinal fluid by the gas entering has been well recognized; but the author introduces another factor, the enlargement of the ventricle. In recent years a number of pathological processes in the brain have been explained only after an investigation of various physical properties of brain structure and it is interesting to see such an application of physical phenomena to explain certain manifestations which have been observed during encephalography. The author then describes a number of experiments with ingenious glass models of the ventricular system to support this theory. The conclusions obtained in this manner are then applied to more practical issues and a number of improvements in technique are described to ensure adequate filling of the ventricles.

Probably the most important contribution in this volume is the work on the encephalographic visualization of abnormalities in the posterior fossa. A method for outlining the basal cisterns and the fourth ventricle is demonstrated and in a series of radiographs and outline drawings the salient points in the text are made quite clear. The chapter is completed by a series of case histories in which the encephalographic findings are well illustrated.

One of the most important applications of encephalography is the differentiation between cerebral tumour and atrophy. The correct interpretation of displacement and asymmetry of the ventricular system is discussed, and it is in relation to this problem that the author shows how it is possible to visualize the position of the falx in routine radiographs and to correlate all the evidence indicating displacement of the ventricular system.

The monograph contains some new developments in technique and the results of experience with a number of different methods of premedication and anaesthesia. With this volume the author has produced a noteworthy contribution in which the work is presented in a logical and consecutive manner. After a number of theoretical considerations, practical points in technique are elaborated and as a result of these the scope and accuracy of encephalography are enlarged. The reproduction of the radiographs has been done with considerable care and indicates a high standard of perfection in radiographic technique; with the interpretive tracings which accompany them, these may well serve as an atlas for reference. This volume, together with its predecessor, contains practically all that is known and much that is new in this method of clinical investigation. It will be of interest not only to the neurologist, neurosurgeon and radiologist, but also to all those who desire a more complete equipment for dealing with the neurological problems in surgery, medicine and paediatrics.

The Peripheral Circulation in Health and Disease. By ROBERT L. RICHARDS, M.D.; 1946. Edinburgh: E. and S. Livingstone. 9 $\frac{1}{2}$ " \times 6 $\frac{3}{4}$ ", pp. 165, with 104 illustrations.

THIS report is a pleasure to handle, being produced with first-class paper and print. The illustrations are also well produced, but it is occasionally difficult to associate the stated sex with the illustration.

The author's theoretical considerations are of no great moment; they contain such statements as that the heat loss from the body surface is 76% by radiation and 24% by evaporation of moisture. These are of course time-honoured figures in British texts of physiology, and completely overlook the different environment in which a man may find himself. The reports upon normal surface temperatures and the reactions to changes of temperature are a good, straightforward account. The chapters on occlusive

vascular disease, the Raynaud phenomenon, peripheral nerve injuries and the immersion syndrome are first-rate accounts of the information to be derived by surface thermometry. It is a pity that this was not supplemented by plethysmography, so that a more comprehensive understanding of the vascular changes could have been presented. One can attach little significance to the inflammatory changes reported in the digital vessels of the case of Raynaud's disease with aseptic inflammation as a result of gangrene. Such changes can be duplicated readily in any form of aseptic inflammation. The above criticisms should not be taken to mean that the publication is not of high merit. It contains the reports of much accurate and painstaking work, and in the present state of knowledge is a very good guide to the interpretation of the findings. Practitioners interested in peripheral vascular disease and the assessment of it by surface thermometry will find this an indispensable publication.

Human Torulosis: A Clinical, Pathological and Microbiological Study with a Report of Thirteen Cases. By LEONARD B. COX, M.D. (Melb.), M.R.C.P. (Edin.), F.R.A.C.P., and JEAN C. TOLHURST, M.Sc. (Melb.); 1946. Melbourne: Melbourne University Press. 10" x 7½", pp. 149, with 67 figures. Price: 25s.

THIS book is an admirable account of torula infection in the human subject. The matter is approached from clinical, pathological and microbiological aspects and may be regarded as an authoritative statement of present knowledge. There is an interesting historical review of the literature and twelve cases of the disease have been studied in detail.

The authors point out that the incidence of torula infection is probably not so rare as has been previously thought. The clinical manifestations of invasion of the various systems have been clearly described and the differential diagnosis from other infections of the central nervous and other systems which torulosis may simulate is well set out.

Particular interest is attached to the section in which fungous infections of the respiratory system are admirably discussed. The case report of the coincident infection by torula and tuberculosis is of great clinical interest.

The morphology in human and animal tissues and in cultures is adequately discussed. The very thick torular capsule is stressed. The authors observed limited formation of hyphae in three of their cultures. They have not observed fusion of hyphae, but quote Todd and Hermann's claim to have noted it in cultures. Calcification of torulae in various lesions in animals has been noted by the authors, though apparently overlooked by most observers. The fermentation reactions, resistance to heat and viability in cultures are also dealt with. Weak and variable serological reactions were obtained with the sera of inoculated animals. The lesions obtained experimentally in mice, rats, guinea-pigs and rabbits are described.

The morbid anatomy and histology of the disease in their cases are systematically elaborated, in particular the lesion in the central nervous system and in the lungs and pleurae; whilst the lesions found in kidneys, suprarenal glands, liver *et cetera* by other authors are reviewed. Both the authors and other observers have claimed the occasional coincidence of torulosis and Hodgkin's disease.

There is a separate chapter on the laboratory diagnosis from examination of the cerebro-spinal fluid, sputum, cultures from naso-pharynx and blood cultures.

The authors discuss the source of torular infection. Definite evidence of cross-infection from man to man has not been proved and the organisms are very widely distributed in nature. The authors believe that the primary implantation is usually in the lungs, from which dissemination takes place to the central nervous system and other organs by the blood stream.

This monograph is well illustrated by seven X-ray photographs of pulmonary lesions and sixty photomicrographs of torulae in exudates, tissues and cultures, and by excellent photographs of affected organs, both macroscopic and microscopic. There is no doubt but that the authors and the publishers, Melbourne University Press, and the medical staff of the Alfred Hospital are all to be congratulated on a first-class wholly Australian production.

The Intervertebral Disc. By F. KEITH BRADFORD, M.D., and R. GLEN SPURLING, M.D.; Second Edition; 1945. Springfield, Illinois: Charles C. Thomas. 10" x 6¼", pp. 192, with 70 illustrations. Price: \$4.00.

BRADFORD AND SPURLING have made many contributions to present-day knowledge of the intervertebral disc, especially in regard to its relationship to sciatic pain. It is no surprise, therefore, to find in the second edition of this monograph the whole story of the intervertebral disc told in a manner that is both concise and authoritative.

Considerable space is devoted to considerations of embryology, anatomy and physiology. These introductory chapters are worthy of careful study because in them one finds most satisfying explanations of the behaviour of the intervertebral disc under stress. That these stresses are considerable is illustrated by what appears to be indisputable evidence that when a man lifts 100 pounds with arms outstretched in front of him the total force exerted on his lumbo-sacral disc amounts to the astonishing figure of 1,600 pounds. A separate chapter is devoted to pathology, and the behaviour of the disc in conditions other than herniation and prolapse is dealt with.

The main interest in the monograph is of course the relationship of prolapse of the *nucleus pulposus* and sciatica. The subject is dealt with in logical sequence. First we find a full description of the clinical and special investigations of patients with low back and sciatic pain. It is of interest to find great store set upon accurate mapping of areas of sensory changes, as a means of determining the level of the lesion. In common with others, we have found these to be so variable as to be confusing. Contrast media (lipiodol and "Pantopaque") are still regarded as indicated "only in those cases which, if verified, are to be operated on". Special indications for myelography include suspected lesions at the third lumbar disc or higher, the presence of spondylolisthesis and suspected multiple lesions. The authors feel that "lipiodol will be largely replaced by pantopaque". Excellent reproductions of skiagrams, illustrating the filling defects in the contrast media in the common types of lesion, are given, together with one showing the X-ray appearance of lipiodol when injected into the subdural instead of the subarachnoid space.

Chapter V deals with the clinical findings in lumbar herniations of the *nucleus pulposus* and this, with the two subsequent chapters on treatment and a general discussion on herniated *nucleus pulposus* and allied conditions, represents the highlight of the volume. It concludes with a full account of the differential diagnosis—and here is listed a formidable array of traps for the unwary.

Possibly the least satisfying section of the monograph is that dealing with conservative treatment. "Laminectomy is indicated . . . failed to improve after adequate conservative treatment . . ." All are agreed on this point, and it is disappointing to find no clearly defined criteria of what constitutes "adequate conservative treatment". The surgical technique advised is a hemi-laminectomy, in which, in the ideal subject, insufficient bone is removed to admit even the pulp of the palpating finger. In such circumstances damage to the spinal column is negligible and full recovery after operation may be confidently anticipated. When there is a large defect in the *annulus fibrosus*, every effort is made to evacuate all the nucleus to minimize the likelihood of recurrence; when the defect is small, it is considered unwise to enlarge it. Though strangely lacking in enthusiasm, the authors appear to favour section of the posterior nerve root to ensure that painful stimuli engendered by irreversible fibrotic changes in the nerve will not jeopardize the success of the operation.

Chapter VIII deals with the relatively rare cervical and thoracic herniations. The last chapter contains a selection of case histories to illustrate the various types of lesions together with the relevant investigations, skiagrams and operative findings.

The illustrations and diagrams, numbering 70 in all, have been carefully drawn and selected, and are in keeping with the high standard of the text. A full bibliography is given at the end of the monograph, which must rank as one of the most important contributions to date on the surgery of the intervertebral disc.

The Chemistry of Anesthesia. By JOHN ADRIAN, M.D.; 1945. Springfield, Illinois: Charles C. Thomas. 9½" x 6½", pp. 502, with 45 figures. Price: \$7.00.

This book is a comprehensive and well-presented study of the chemistry of anaesthesia, and is probably of more value to the specialist anaesthetist and those studying for post-graduate anaesthetic degrees than to the medical student. It is divided into three parts: Part 1, inorganic chemistry related to anaesthesia; Part 2, organic chemistry related to anaesthesia; Part 3, biochemistry related to anaesthesia. While this may appear formidable to those who have lost contact with the chemistry of the earlier years of their medical course, it need not do so, as the book is written for anaesthetists rather than for chemists or pharmacologists, and lucid explanations of fundamental facts and principles of chemistry are given, which enable the reader to assimilate the subject the more readily.

The opening pages of Part 1 are given to simple presentations of the physical laws of gases—the laws of Boyle, Henry, Graham, Avogadro *et cetera*. Then follow the chemistry of oxygen, nitrogen, nitrous oxide, carbon dioxide, helium and hydrogen, and a full chapter on absorption of carbon dioxide and rebreathing appliances.

Fifteen chapters are devoted to Part 2, and include the whole range of anaesthetics, inhalation and local anaesthetic drugs, narcotics, hypnotics *et cetera*.

In Part 3—biochemistry related to anaesthesia—the ground is similarly well covered and includes chapters on the effects of anaesthesia upon composition of body fluids, liver function, lipid and nervous tissues.

Finally, there is appended a most extensive bibliography, with a glossary and table of irritating gases, and gases used in warfare.

The book is a valuable contribution to the study of anaesthetics.

A Complete Outline of Fractures. By J. GRANT BONNIN, F.R.C.S.; Second Edition; 1946. London: William Heinemann. 8½" × 5½", pp. 672, with 712 illustrations. Price: 30s.

The second edition of this work is larger than the first and has been considerably recast. It therefore becomes less an "Ideal Student's Text Book" and more a work of reference.

When compared with similar works in the latter field its clarity and conciseness compensate for the quality of many of its illustrations. The inclusion of the modern ideas about mechanical fixation combined with chemotherapy, of war and facio-maxillary fractures, and of the surgical approach to the long bones, enhances the value of a good book.

Few who have had experience of fractures of the carpal navicular bone in the services will agree with the author's teaching that immobilization need not include the thumb. Nor will it be generally conceded that the author has clarified for the student the difficult subject of fractures of the ankle joint.

Mr. Barron's excellent contribution on facio-maxillary fractures has failed to reach the completeness which one would expect in a work of reference, probably because he has striven to achieve that simplicity desirable in student teaching. But these are carping criticisms of a commendable work which will enjoy a wide appeal to undergraduates and graduates.

The Medical Annual: A Year Book of Treatment and Practitioner's Index. Edited by SIR HENRY TIDY, K.B.E., M.A., M.D. (Oxon.), F.R.C.P., and A. RENDLE SHORT, M.D., B.S., B.Sc., F.R.C.S.; 1945. Bristol: John Wright and Sons, Limited. 8½" × 5½", pp. 438, with 61 figures. Price: 25s. net.

We do no more than make formal and very welcome acknowledgement of this time-honoured yearly production. It is indeed good to note the editors' belief that after six long years their volume may shortly be immune from the rigors of all sorts of rationing and regain its pristine distinction. We congratulate all concerned with the production of the volume and indeed on the way in which through the years of war they were able to maintain a high standard in this publication.

The X-Ray Treatment of Accessible Cancer. By D. WALDRON SMITHERS; 1946. London: Edward Arnold and Company. 10½" × 7½", pp. 155, with 12 illustrations. Price: 40s.

The radiation specialist has a variety of apparatus available for the treatment of cancer. Radium and radon, high and low voltage X-ray machines all have their particular uses and indications. D. W. Smithers, in his book "The X-Ray Treatment of Accessible Cancer", considers the place of low voltage equipment in dealing with tumours in those sites where the low depth doses obtainable can be put to effective use. He deals with a specialty within a specialty, and the book is therefore addressed primarily to the radiotherapist.

The author's work brings him into close contact with overlapping surgical and radiational problems, and in these pages it is of interest to note his views on the place of surgery. A small proportion of basal-cell and squamous-cell carcinomata of the skin are found to be resistant to ordinarily adequate doses of radiation and exhibit incomplete resolution after treatment. Surgical excision of the residuum should be carried out. However, radiation remains the treatment of choice for cancer of the skin.

Epithelioma of the lip is treated by the author with external irradiation with results as satisfactory as those produced by radium. The cosmetic effects obtained with radiation contraindicate surgery to the primary growth. Prophylactic excision of glands is not necessary in early, small or differentiated lip carcinoma, but neck dissection should be carried out in later stages of the disease.

Radiation does not always produce complete recession of carcinoma of the tongue, especially if lingual fibrosis or a specific basis preexists. Excision of the residuum is then needed and for some cases within this category the author prefers surgery to radiation, but, strangely, does not insist on excision of the glands in all early cases. The advantages of immediate surgery for carcinoma invading the alveolus are stressed,

as removal of the growth by radiation leaves exposed eroded bone, which becomes necrotic and infected.

In some inoperable cases of carcinoma of the rectum the growth has been brought to the surface by surgery of access for superficial radiation therapy. The author considers external high voltage X-ray therapy of greater value for palliative purposes. Carcinoma of the bladder responds well to radiation following cystostomy. The use of an intravesical X-ray applicator has no advantages over radium implantation.

The book is profusely illustrated with excellent photographs and diagrams. The production is a credit to the author and the publishers.

Demonstrations of Physical Signs in Clinical Surgery. By HAMILTON BAILEY, F.R.C.S., F.I.C.S.; Tenth Edition; 1946. Bristol: John Wright and Sons, Limited. 8 $\frac{3}{4}$ " \times 5 $\frac{1}{2}$ ", pp. 387, with 573 figures. Price: 30s.

THIS excellent book needs no introduction. It is now in a tenth edition, having run through three editions in the war years, the last in 1944. The author now seems to have adopted a routine of a new edition each alternate year, and each time more profusely illustrated.

The book is intended, as the author states, for demonstrations of physical signs, and this it does most excellently. There are half as many photographs or diagrams again as there are pages. Colour photography is used more extensively and is most laudably reproduced. The general arrangement of the text is much as in previous editions. The quality of the printing, binding and paper is up to the previous high standard.

This book will be, as before, of great value to the student and also to the graduate. It is simple, clear, very readable and admirably illustrated.

Injuries to the Knee Joint. By I. S. SMILLIE, O.B.E., M.B., F.R.C.S.E., F.R.F.P.S.; 1946. Edinburgh: E. and S. Livingstone, Limited. 9 $\frac{1}{2}$ " \times 6 $\frac{1}{2}$ ", pp. 320, with 350 figures. Price: 35s.

THIS book of 300 pages is an account of the author's personal experience in dealing with 5,000 patients suffering from complaints directly related to the knee joint. This is a formidable score, justifying the production of some original opinions.

In the first section, which deals with lesions of the menisci, there is a detailed account of the mechanism of production of the injury. Although this is sometimes hard to follow, it is plausible and provides an explanation of the various tears and detachments. It is peculiar to find no mention whatever of lesions of the anterior end, or of "loose anterior attachment". In view of the frequency of this as a post-operative diagnosis, generally to justify the removal of a normal meniscus, it should be worth mentioning, if only to emphasize its extreme rarity. The difficulties of diagnosis are well described and the pitfalls indicated. The operative detail, including the use of the author's ingenious knives, is good. It is refreshing to read of the importance of post-operative treatment and muscle training, and that "receptive therapy is of strictly limited application in all orthopaedic cases". No mention is made of heavy resistance exercises, which are now advocated to produce power in muscles, as contrasted with the endurance produced by repetition exercises. In assessing end results the author considers that many failures are due to delay in surgical intervention. He considers that a damaged meniscus should be removed promptly and completely. In over 1,000 operations for menisci he confesses to having removed 7.2% of normal structures. Most surgeons would agree that this figure is good.

The section on injuries to the ligaments contains a description of the author's method of reconstruction of the cruciates by use of the peripheral portion of the meniscus as a new ligament. The remainder of the book, devoted to injuries to muscles, bones and bursae, with chapters on loose bodies, wounds and the stiff knee, contains many useful technical points. Among these is a clever method of fixing the transplanted tibial tubercle and a new method of obtaining full extension of the knee joint.

Altogether this is an interesting and valuable expression of opinions and methods. The book is beautifully got up, the paper and printing are excellent, and the illustrations first class. The author's line drawings are clear and striking. Errors are few, but one of our most famous Australians is referred to three times in one paragraph as a 'platybus'. On page 239 the illustration shows the usual forward displacement of the lower femoral epiphysis, not a backward displacement as the caption reads.

